LATE STANDARDIZATION AND TECHNOLOGICAL CATCH-UP

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Submitted to the Department of Urban Studies and Planning
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy in Economic Development and Technology Policy

at the

Massachusetts Institute of Technology

September 2006

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ABSTRACT

In this study, we examine the process of "late standardization," in which latecomers engage in standards activities in order to move towards and beyond the technological frontier. Based on case studies of latecomers in the semiconductor and mobile telecommunication industries in South Korea and Thailand, we analyze the strategic, organizational, and institutional aspects of the late-standardization process.

We hypothesize that latecomer firms and states must engage in standards activities to progress beyond catch-up, because standards are a prerequisite to technological development. Standards are strategic leverages that allow latecomers to link with and learn from technology leaders. Specifically, latecomer firms have to engage internally in quality standardization to take advantage of latecomer advantages. Quality standards help improve production capability, while enhancing credibility and reputation. Without quality control, latecomers cannot become part of global value chains and have difficulty in acquiring advanced technologies from forerunners.

As latecomers become fast followers, they have to participate in external standardization. The goal is to acquire knowledge about emerging technologies and standards. By linking with and learning from forerunners, fast followers enhance second-mover advantages derived from ramp-up capability. Once their R&D efforts bear fruit and they become technology leaders, advanced "late standardizers" have to lead external standardization efforts. This would enable them to exploit innovation capability and gain first-mover advantages derived from proprietary technologies and learning-curve effects. As latecomers move towards the technological frontier, standards activities become the core of research and development strategy and policy. They also adjust organizational structures and human resource management to accommodate standards efforts.

The state plays critical yet changing roles throughout the late-standardization process. It sets up standards institutions and provides "infratechnologies" for quality control. The state also mitigates technology and market risks associated with new standards, while facilitating networking among late-standardizing firms. As late standardizers become technology and standards leaders, the state pursues "standards diplomacy" for overseas adoption of its domestic standards, while strengthening the protection of intellectual property rights.

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ACKNOWLEDGMENTS

While time and space for acknowledgments are limited, the generosity and kindness extended to me have been boundless.

I am grateful for the support and encouragement that I received from my dissertation committee. I would like to thank Professor Alice H. Amsden for the intellectual stimulation and inspiration since my first term at MIT. I became interested in industrial and technology policy from the very first class in her course Economic Development and Industrial Policy. I would like to thank Professor Karen R. Polenske for her academic guidance and emotional support. I am particularly grateful for her selecting me to work on the book "The Economic Geography of Innovation." I am grateful to Professor Calestous Juma for his encouragement and helpful comments. With his kind help, I received an internship at UNCTAD, where I first became interested in standards.

I sincerely appreciate Professor Bish Sanyal's support and his intellectually challenging questions. Although my doctoral research has nothing to do with transportation planning, I benefited greatly from my previous research work for Professor Ralph Gakenheimer.

I am indebted to all the experts who kindly assisted me, in one way or another, during my field research: Mian Quddus, Sanghoon Lee, Huemjeng Kang, Osok Song, Jinsung Choi, Hong-Lim Lee, Juyeon Song, Dong Yang Lee, Jang-Sup Shin, Chaisung Lim, Seungmin Benjamin Lee, Patrick Moran, T.W. Kwon, J.K. Kim, B.K. Ng, Gil Russell, Desi Rhoden, Ming-Feng Yen, Art Kilmer, Arnon Tuntiang, Wichian Mektrakarn, Montakarn Ahkuputra, Patarapong Intarakumnerd, and Narat Rujirat.

My doctoral studies would not have been possible without the help from the administrative staff in DUSP: Sandy Wellford, Alice Twohig, Nimfa de Leon, Karen Yegian, Phil Sunde, and many others.

I greatly appreciate the following institutions for their generosity that has financially supported my academic endeavor: Harvard Yenching Institute, MIT Center for International Studies, MIT Industrial Performance Center, Cambridge-MIT Institute, Harvard Belfer Center for Science and International Affairs, the Rodwin Family, the Emerson Travel Fund, and the Royal Thai Government.

Further thanks go to all my friends at MIT and beyond, who help me save my sanity throughout this long process. Thumper and Tigger, I thank both of you for keeping my lap warm while working on the manuscript.

Last but certainly not least, my graduate studies in the United States would have been impossible without the unconditional love and support from my family in Thailand and Massachusetts.

CONTENTS

TABLES

FIGURES

CHAPTER ONE

STANDARDIZING LATE

STANDARDS AND TECHNOLOGICAL CATCH-UP ■ RESEARCH QUESTIONS AND HYPOTHESES ■ RESEARCH DESIGN ■ SKIMMING THE SURFACE: MAIN FINDINGS ■ STRUCTURE OF DISSERTATION

Pessimism abounds regarding the effects of technical standards on technological catch-up. For many a practitioner and academic, technical standards constitute additional barriers against firms in developing countries that wish to penetrate into the world market. Such pessimism carries some truth. Standards determine the forms, functions, and other characteristics of products, as well as the ways in which firms produce them. Stringent standards may raise compliance costs, which could be prohibitive to latecomer firms.

This pessimism, however, often undermines the appreciation of the fundamental roles of standards in catch-up efforts. One basic role of standards is to convey technical information about products and processes. More publicly available standards mean there is more public knowledge for latecomers to utilize without investing heavily in research and development (R&D). Standards thus present both obstacles and opportunities for developing countries.

This study is a response to such pessimism by examining how some latecomers have managed to turn the obstacles into opportunities and become standards leaders in their own right. We start by asking the question: *What are the implications of technical standards for technological catch-up by latecomers?* In answering the question, we examine the process of "late standardization", in which latecomers engage in standards activities in order to move towards and beyond the technological frontier.[1] Based on case studies of "late standardizers" in South Korea and Thailand, we develop a conceptual model of late standardization and technological catch-up. We then analyze the strategic, organizational, and institutional aspects of the late-standardization process.

The main premise of our research is that latecomers are not the original developers of standards. Because of limited resources and capabilities, latecomers adopt, diffuse, and maintain standards in order to produce and sell their products in the world market. They are standards followers during the technological catch-up process. Yet, some latecomer firms, such as South Korea's Samsung Electronics and LG Electronics, have in recent years emerged from being followers to become leaders at the world technological frontier. Not only have they become technological leaders, but they have also become standards leaders.

We argue that latecomer firms and states must engage in standards activities to progress beyond catch-up, because standards are a prerequisite to the development of science, technology, and innovation. Standards are a strategic leverage that allows latecomers to link with and learn from technology leaders. Specifically, latecomer firms have to engage internally in quality standardization and control to become fast followers of advanced technologies. Quality standards enable them to improve production processes, while enhancing credibility and reputation. Without improving quality standardization and control, latecomers cannot become part of global value chains and find it more difficult to acquire advanced technologies from technology leaders.

We further argue that, as latecomers become fast followers, they have to participate in external standardization. The goal is to link with technology leaders to acquire knowledge about emerging technologies. By linking with and learning from forerunners, fast followers enhance their ramp-up capability, the main source of their second-mover advantage. Standards thus allow fast followers to enhance their production speed and volume.

Finally, once their research and development (R&D) efforts bear fruit and they become technology leaders, advanced "late standardizers" have to lead standardization efforts. The standards leadership would help sustain their first-mover advantage derived from proprietary technologies and learning-curve effects.

Meanwhile, the state plays a critical role throughout the late-standardization process. It sets up institutions for standards activities and provides infratechnologies for quality control, such as measurement and reference standards.[2] The state also plays important roles in mitigating technological and market risks, facilitating networking among late-standardizing firms, lobbying for expansion of overseas markets, and protecting intellectual property rights.

We conduct this research as a response to the increase in practical importance and academic interest in standards. Technical standards have increasingly important implications for technological and economic development of latecomers, both positively and negatively. Standards are fundamental because they determine the forms, functions, and other characteristics of products, as well as the ways in which firms produce them. They also play a fundamental role in conveying the technical information about certain products and processes. More publicly available standards mean there is more public knowledge for late standardizers to utilize without investing heavily in basic R&D. However, more standards also provide firms with more technical obligations to comply with and hence greater barriers against their technological efforts. Standards present both obstacles and opportunities for late standardizers. There has been much concern among development scholars and practitioners that standards negatively affect developing countries' economic development. In this study, we intend to show how successful late standardizers manage to turn the obstacles into opportunities and become standards leaders in their own right.

Although standards have always been crucial to technological development, several factors have contributed to their increased importance in the past few decades. First, information and communications technology (ICT) industries have become the key engine of technological and economic change, both in developed and developing economies. In fact, several successful catch-up efforts by late standardizers, notably Samsung Electronics, have occurred in these sectors. Second, because of the network and system characteristics of ICT products, an increasing number of standards are required to ensure their compatibility and interoperability. Third, increasing complexity of products and services require more standards, not only for their compatibility but also for their reliability and safety. Finally, the globalization of trade and investment means that products are produced and purchased in different locations across the globe than they were 20 years ago. While standards are usually developed to help facilitate technical and economic transactions across borders, they could be used as a protectionist measure to nurture domestic industries during the early years of late standardizers' technological development.

There is now substantial literature on standards and standardization. There is also a large body of literature on late industrialization and technological catch-up by latecomers. Surprisingly, however, the literature on the relationship between standards and technological catch-up is scarce. We know very little, both theoretically and empirically, about how standards and related efforts affect late standardizers' technological catch-up processes.

WHY STUDY STANDARDS AND TECHNOLOGICAL CATCH-UP?

The rationale underlying this research is threefold: (1) the increasing importance of standards in terms of contribution to technological and economic development, especially for latecomer countries, (2) the recent emergence of some latecomer firms as standards leaders, and (3) the limited literature on the relationship between standards and technological catch-up.

(1) INCREASING IMPORTANCE OF STANDARDS

Standards have increasingly important implications for technological development. Technical standards are fundamental because they determine the forms, functions, and other characteristics of products, as well as the ways in which firms produce them. Standards and related activities have wide-ranging implications for firms, industries, and nations. As standards define the general concept of a technology system and its design configuration, they affect both the generation and the limitation of innovation and technological diffusion. Standards contain knowledge and product elements, which affect technological change when they are combined. By reducing technological uncertainty, standards guide the pattern of technological change in fruitful directions, while permitting variations therein. We discuss this issue further in Chapter Two.

We explain why three main factors have contributed to the increasing importance of standards in the past few decades. These factors include: (i) ICT industries as the key engine of technological change and economic development, (ii) increasing complexity of products and services; and (iii) globalization of trade and investment.

ICT as the engine of technological and economic development

Information and communications technology (ICT) industries have recently become the key engine of technological and economic change both in developed and developing economies. Their important contribution to economic development is evident. As shown by Jorgenson and Vu (2005), the contributions of ICT investment to economic growth and productivity have increased in seven regions and 14 major economies in the world during the period 1989-2003. The impact is particularly significant in industrialized economies and developing economies in Asia. Similarly, a report by the Organisation for Economic Co-Operation and Development (OECD) shows that the quality of ICT goods and services continues to improve, driving prices down and leading to a widening range of new applications. ICT represents an increasingly substantial part of the added-value of products and services. Individual consumers are becoming used to ICT, and business-to-consumer electronic commerce has started to follow the lead that business-to-business electronic commerce set in the 1990s (OECD 2003). As an example at the national level, the ICT sector accounted for about 18 percent of South Korea's Gross Domestic Product (GDP) in 2003 and 30 percent of the total export value for the same year (Bank of Korea 2004). The use of ICT technologies is now prevalent in every sector of the economy. ICT-intensive sectors include financial services, media and retail, automotive, aerospace, and healthcare (ITU 2003).

Historically, most latecomers focused their early technological efforts on heavy industries, such as steel, petrochemicals, automobiles, and the ship-building industries (Amsden 2001). In recent years, however, some successful technological catch-up efforts occur in the ICT industries. Several latecomer firms have emerged as technological leaders in some segments of the industry, such as Samsung and LG from South Korea, and TSMC and Acer from Taiwan (Amsden and Chu 2003).

The increasing importance of the ICT industries consequently raises the significance of standards. Because of the network and system characteristics unique to ICT products, standards are required to ensure compatibility between different components and products in the same systems. Compatibility standards allow producers and users to benefit from interconnected networks of hardware and software products.

Increasing complexity of products and services

As products and services become more complex, standards play larger roles in facilitating business and technical transactions among the interconnected systems of hardware and software, among engineers and managers, and among buyers and sellers. The increasing complexity of products and services means that the production and distribution along the supply and value chains become more complex as well. Complex supply chains further need more co-ordination to secure the compatibility, interoperability, and reliability of all the elements involved. In various ways, standards function as the connection among the products and services, as well as the production and distribution processes.

Globalization of trade and investment

The relationship between standards and international trade has changed significantly in the past two decades. Globalization of trade and investment further demands new standards that facilitate communications and transactions across borders. As globalization of trade and investment continues, standards are increasingly viewed as another type of international regulation that restricts the flows of trade and investment. Although the Uruguay Round of multilateral trade negotiations and other trade agreements have substantially reduced tariffs and quantitative restrictions on products across borders, standards and technical regulations increasingly appear as the main impediments to international trade.

It is rather ironic that standards are often considered by many trade negotiators as technical barriers to international trade. Historically, standards were developed as a means to facilitate trade. For instance, standard weights and measures were used to describe goods exchanged in the market, as well as to prevent fraud. Standardized electrical voltage allows consumers to use electrical appliances in different regions (Krislov 1997). Safety regulations were enforced to protect consumers of imported foodstuffs and other products. Common currencies, such as the Euro, were developed and are used largely to increase trade among nations.[3] In addition to controlling the quality of imported goods, governments may also use standards as a means to improve and maintain the quality of the products that they export to the world market (Krislov 1997; Verman 1973).

Standards may differ across countries because of diverse consumer preferences, income levels, technologies, or resource endowments (Sykes 1995). However, standards may also be used as a protectionist tool. In order to develop indigenous technologies, many governments shield local industries from foreign competition by implementing policy measures that, in effect, impose a cost disadvantage on foreign firms (Wilson 1995). Standards and the methods of assessing conformity to standards are among the various measures that are available to them. This problem is expected to escalate, as globalization of production continues and more parts and components are sourced from different countries. Standards have thus become a main issue in international trade policy debates.

(2) THE ASCENT OF "LATE STANDARDIZERS"

The recent emergence of "late standardizers" as standards leaders in the ICT industries is another rationale for conducting research on late standardization and technological catch-up. Examples of these "late standardizers' include Samsung Electronics and LG Electronics from South Korea, TSMC and Acer from Taiwan, and Huawei Technologies and ZTE from China. As we will show in subsequent chapters, standards leadership is manifested through their noticeable influence on international standards development. Although the number of such late standardizers is still small, their recent technological and standards leadership indicates a significant development, which deserves systematic theoretical and empirical research.

Historically, firms and governments in industrialized countries have always been the main actors in international standardization efforts, mainly because of their technological leadership. They produce the majority of the world's voluntary industry standards as well as de facto standards. Latecomer firms and their governments may develop some technical standards unique to their domestic markets. But they have limited involvement in developing technical standards at the international level, and generally adopt standards developed in advanced economies, including their former colonizers. (United Nations 1964; Stephenson 1997)

The emergence of late standardizers as standards leaders since the late 1990s thus indicates a significant development. It is true that advanced economies still dominate the major standardization forums, such as the International Organization for Standardization (ISO) and the International Telecommunication Union (ITU). However, an increasing number of late standardizers have significantly increased their presence in formal standards development organizations (SDO). Notable examples include South Korean and Taiwanese firms in the ISO and the ITU. Meanwhile, standardization at the technological frontier increasingly occurs outside formal SDOs, either in standards consortia or among coalitions of firms (Weiss and Cargill 1992). As we will show in detail in Chapter Three, an increasing number of late standardizers from South Korea, Taiwan, Singapore, and China have joined these "informal" standards forums. They have in effect become part of the standards clubs that often determine the rates and directions of technological development in their particular industries.

(3) Limited Literature on Standards and Technological Catch-up

Standards have increasingly become a subject of academic enquiry. The literature on standards comprises work by scholars in various fields, ranging from economics and management to political science, public policy and law. For instance, within the literature on the economics of standards, one of the main focuses is on the strategic interactions between firms regarding standardization strategies for products in network industries. Many of these studies examine the production and consumption of standards by technological leaders and the advantages accruing to them (e.g., Farrell and Saloner 1985; Katz and Shapiro 1986). Others focus on the user side, paying attention to the costs and benefits of variety reduction due to standardization (e.g., Farrell and Saloner 1986). The institutional aspects of standards and standardization activities have recently been evaluated by an increasing number of case studies of standardization organizations (e.g., Schmidt and Werle 1998; Loya and Boli 1999; Werle 2001). A few of these studies deal with governance and political issues of international standardization (e.g., Krasner 1991; Mattli 2001; Mattli and Buthe 2003; Drezner 2004).

Most analysts writing on standards focus on firms and institutions in industrialized countries that are standards leaders. We know very little about firms and governments that engage in various standards-related activities when they do not possess cutting-edge technologies. Meanwhile, among the authors writing on standards issues in developing countries, most deal with international environmental and labor standards in the context of trade agreements (e.g., Busse 2002). There are a few analysts who examine the impacts of standards on developing-country firms, but their focus has been on the costs and benefits of compliance with foreign standards mostly in the agricultural sector (e.g., Otsuki et al. 2001; Wilson and Otsuki 2002). Among studies on standards adoption by latecomers, most analysts examine the ISO 9000 and the ISO 14000 standards (e.g., Huarng et al. 1999; Calisir et al. 2001; Martinez-Costa and Martinez-Lorente 2003). Again we know little about the impacts of voluntary technical standards on latecomer firms.

On the other hand, there is now a voluminous literature on technological catch-up and late industrialization. This includes the pioneer contributions of Veblen (1915) and Gerschenkron (1962), who focus on the European catch-up prior to the First World War. Their analyses shed light on the roles of policy and institutions in Germany and other continental European countries in catching up with Britain. Another subset of the catch-up literature focuses more on recent cases of late industrialization, such as Japan (e.g., Johnson 1982), South Korea (e.g., Amsden 1989), and Taiwan (e.g., Wade 1990). The central argument of this strand of catch-up literature is on the roles of developmental states in successful late industrialization. Another strand of literature on catch-up is led by the work of Abramovitz (1986) whose macro-level analysis examines long-run, cross-country data on economic growth and the factors that affect catch-up and convergence.

Recently analysts examine some of the more successful late industrializers in East Asia, focusing on how they have managed to move beyond technological catch-up (e.g., Mathews 2002; Amsden and Chu 2003). Although these analysts have contributed greatly to the understanding of the catch-up processes, they have not analyzed an important aspect of industrialization, i.e., standardization. We know very little about how latecomers deal with different types and levels of technical standards and related activities, how standards affect technological development and competitiveness, and how some of them have managed to move beyond being standards followers to become standards leaders at the technological frontier. These issues have yet to be assessed systematically via primary empirical research.

RESEARCH QUESTIONS AND HYPOTHESES

As stated at the beginning, our overarching research question is: *What are the implications of standards for technological catch-up of latecomers?* We can paraphrase the question as: *What is the relationship between late standardization and technological catch-up?*

Our general hypothesis is that *latecomers must engage in technological standardization to move beyond technological catch-up, to keep up with technological change, to forge ahead of the forerunners, and to sustain its technological leadership.* In other words, *standards and related activities enable firms to move beyond being latecomers to become second movers,* *and eventually first movers.*

In testing the above hypothesis, we examine four specific aspects of late standardization: (1) types and sources of standards and related activities that affect technological catch-up; (2) resources and capabilities for standards efforts; (3) organizational structure for standards activities; and (4) institutional arrangement and the role of the state that affect standards efforts. These four aspects lead to the following specific sub-hypotheses.

The first sub-hypothesis is that *successful late standardizers develop through distinct stages of late standardization and technological catch-up.* To test this hypothesis, we examine whether late standardizers progress through a series of discrete stages over time, each of which constitutes different types of standards activities, possess distinct sets of standards resources and capabilities, participate in different types of standards forums, and have different organizational structures for standards activities.

The following sub-hypotheses concern the types of standards activities that affect each stages of late standardization and technological catch-up. Our second sub-hypothesis is that *internal quality standardization enhances latecomers' production capability.* Quality standards and related activities offer latecomers the opportunities to learn about relatively mature technologies, as well as new businesses and markets. Particularly, quality standards allow latecomers to leverage their limited resources and capabilities through internal standardization and external linkages with technological leaders. Quality is the key to becoming part of global value chains, which are the main sources of technical and business knowledge necessary for technological upgrading. By engaging internally in quality standardization, latecomers can move beyond catch-up and become fast followers

Our third sub-hypothesis is that *participation in external standardization enhances fast followers' ramp-up capability.* For fast followers, ramp-up capability is the key source of second-mover advantage. They generally improve high-volume-production capability by relying on the knowledge about emerging technologies and superb process technologies. Standards activities enable them to improve both sources of ramp-up capability. As fast followers improve technology capabilities through various R&D efforts, they move closer to the world technological frontier and eventually become technology leaders themselves.

Our fourth sub-hypothesis is that, *leading external standardization enables technology leaders to exploit innovation capability.* Generally, first movers are technology leaders that gain their competitive advantage from various sources, especially technology leadership. Standards leadership reinforces technology leadership, enabling first movers to reap technological rents derived from proprietary technologies and learning-curve effects.

Finally, with regards to the roles of the state in late standardization, our fifth sub-hypothesis is that *the role of the state remains important throughout the process of late standardization.* Yet, the state adjusts its roles from being the main developer and enforcer of standards to become a mediator and coordinator of domestic and international standardization efforts. In other words, the state and other standards institutions co-evolve as late standardizers move towards and beyond the technological frontier. The main goal of the state is to help latecomers increase standards capabilities, such that they can leverage limited internal resources and capabilities through Linking and Learning mechanisms.

We pay additional attention to three factors in examining the above hypotheses: (1) the characteristics of the industries in which catch-up occurs, (2) the technological conditions of such industries, and (3) the degree of backwardness of latecomers compared to forerunners.

CONCEPTUAL FRAMEWORK

As the conceptual starting point, we develop a staged model of late standardization by extending the limited set of empirical and theoretical studies regarding standards and technological catch-up. We draw mainly upon several relevant strands of literature. While all this literature serves as the foundation of our research, each study contributes specifically to the discussion on the four different aspects of late standardization mentioned above.

We first start from two strands of literature: one on innovation dynamics and the technology life cycle (e.g., Abernathy and Utterback 1978; Utterback 1994) and the other on late industrialization and technological catch-up (e.g., Gerschenkron 1962; Abramovitz 1986; Hikino and Amsden 1994). As we incorporate the concept of competitive advantage into the conceptual framework, we build upon the strategic-management literature, particularly those studies that focus on competitive advantage and the order of market entry (e.g., Porter 1985; Teece 1986; Lieberman and Montgomery 1988; Christensen et al. 1998) and those on the resource-based theory of firms (e.g., Penrose 1959/1995; Wernerfelt 1984; Barney 1991).

Our discussion on the role of the state in the late-standardization process is built upon two strands of literatures: (1) the literature on late industrialization mentioned above; (2) the literature on standards and technological infrastructure (e.g., Link and Tassey 1988; Antonelli 1994; Tassey 2000). We will review each of these studies in detail in the respective chapters.

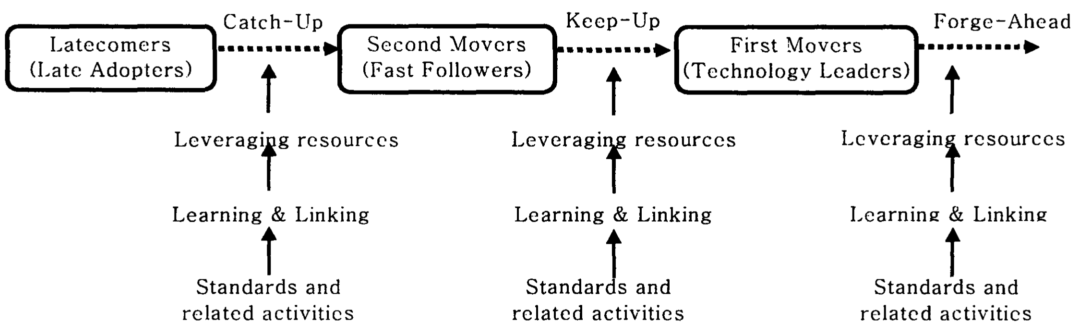
Three key ideas form the basis of our conceptual framework: (1) technological catch-up as a process of improving competitive positions; (2) latecomers as late-movers with additional constraints in terms of resources and capabilities; and (3) standards as linking and learning mechanisms for latecomers to leverage limited resources. We integrate the three concepts into a staged model to illustrate how the three elements play a role over time during the course of late standardizers' development.

In our staged model, late standardizers develop through three distinct stages: catch-up, keep-up, and forge-ahead. This model is based on the observation that catch-up is essentially a process in which latecomers move up on the ladder of competitive positions. They progress from the position where they are constrained in terms of resources, capabilities, and market access, to the position where they exploit proprietary technologies and assets. Put differently, they move from the situation in which market entry is late by necessity to the situation in which they can choose either to be an early or a late mover (Mathews and Cho 2000).

The first stage of catch-up occurs when late standardizers attempt to overcome latecomers' unique constraints, such that they progress from being late adopters to being fast followers in terms of technological adoption. Put differently, in terms of competitive positions, they develop from being latecomers to being second movers. Once they become fast followers, late standardizers have already established themselves as key players in mature product markets. The second stage of keep-up refers to the process in which second movers attempt to become first movers. They aspire to close the gap with the world technological frontier. Finally, the forge-ahead stage is when first movers maintain their leadership, not only in terms of market share and technology, but also in terms of standards.

During different stages of late standardization and technological catch-up, late standardizers utilize different mechanisms to sustain and gain competitive advantage from various sources. In this research, we examine how standards and standards activities contribute to late standardizers' efforts in creating and capturing competitive advantage through Learning and Linking mechanisms such that they can leverage their limited internal resources and capabilities. We summarize this conceptual framework in Figure 1.1.

Figure 1.1: Late Standardization, Technological Catch-Up, and Competitive Positions



Our model of late standardization is an evolutionary model, in that it demonstrates a simplified pattern of a dynamic and historical process. Because the research focus is on the dynamic process of late standardization in the context of catch-up, the evolutionary framework is thus appropriate as the analytical approach. By definition, technological catch-up processes are evolutionary, in that they are dynamic and historical. The model assumes that the process of late standardization and technological catch-up is path-dependent and irrevocable. It is path dependent, because the characteristics of an earlier stage determine those of the following stages. More specifically, the model assumes that technological and standards capabilities are cumulative and that the capabilities that late standardizers acquire in an earlier stage establish the basis for capability building in the following stages. In addition, the process is irrevocable, because it does not repeat itself identically, even though certain patterns may recur in the historical process. In other words, even though late standardizers undertake similar standards activities, such as acquisition, implementation, assimilation, and improvement, the characteristics of the activities are not exactly the same in different stages.

As in any staged models, the underlying assumption is that there is a series of discrete stages over time, each of which constitutes different activities, capabilities, competitive positions, organizational structure, and so forth. We argue that in different stages of late standardization, latecomer firms engage in different types of standards activities. They possess distinct sets of standards resources and capabilities, participate in different types of standards forums, have different organizational structures related to standards, and occupy different competitive positions in the market. In addition, the roles of the state and institutional arrangements are also distinct in each of the three stages.

RESEARCH DESIGN AND METHODOLOGY

We adopt the case-oriented approach as the primary methodology for exploring the above research questions. Although the main unit of analysis is the latecomer firm, we also examine non-firm institutions of latecomer countries, such as research and legal institutions, in order to test the fifth sub-hypothesis on the role of the state in late standardization.

Specifically, we adopt the prototypical-case-study approach, a type of crucial-case-study approach, with shadow cases to test the main hypothesis and five sub-hypotheses and to generalize the findings. The prototypical case is different from a representative case study in that the case is chosen not because it is representative, but because we expect it to become so. As Rose (1991) argues, studying an early prototypical example may help us to understand a phenomenon of growing significance. We study specific prototypical cases, because they embody or exemplify an archetype of a phenomenon. With regards to theoretical contribution, a prototypical case-study may eventually lead to theory-generating, or what Eckstein (1975) calls the "probability-probe" in a situation when there is not yet a theory to be tested or confirmed. The approach may also be used when there is some sort of 'proto-theory' which the analyst wants to test and refine (Landman 2000). In our study, the prototypical case-study also offers practical opportunities for lesson-drawing; other latecomers may be able to learn from the experiences of successful late standardizers in terms of standards strategies and policies. In the sections below, we provide the details on the case selection and data collection.

CASE SELECTION

We select South Korean firms as our prototypical cases and Thai firms as our shadow cases, where we use the latter cases to provide a cross-country comparison. We choose firms in two industries in which the late-standardization phenomenon has been prominent: semiconductor and mobile telecommunication.

Country: Korean firms as prototypical cases, Thai firms as shadow cases

We select our case studies in a strategic way, such that the selected cases are "prototypical" to our topic. We select South Korean late standardizers as the prototypical cases for this research. Among the limited number of latecomer firms and countries that have emerged as standards leaders, South Korean latecomers are the most prominent. Since the rise of Japan as a technological and standards leader in the 1970s, South Korea is one of very few latecomer countries that have emerged from being technological and standards followers to leaders in recent decades. South Korean latecomer firms have caught up and kept up with the technological changes introduced by the forerunners in the Triad countries, that is, the United States., the European Union, and Japan. Some of them, such as Samsung Electronics and LG Electronics, have already exhibited technology and standards leadership in several technical areas, notably in semiconductor and telecommunications.

Even though South Korean firms and institutions are unique in many ways, their standards efforts during their early years of late standardization and their successes in the recent years make them the best candidates for research on late standardization and technological catch-up. Taiwan is another potential case study. However, because of its limited diplomatic status, Taiwan cannot participate in most formal international standards organizations, such as the International Organization for Standardization (ISO). Considering that until recent years, most standardization activities occurred in these forums, and that Taiwan was not part of them, South Korea thus appears to be the best candidate for the study. By studying its standards issues, we hope to be able to examine how a latecomer manages to upgrade its status from being a standards follower to a standards leader, and the implications of standards for technological catch-up in general.

On the other hand, we select latecomer firms and institutions in Thailand as the "shadow cases". The purpose of using shadow cases is to improve generalizability of the research results. While the Korean prototypical cases offer *within-case evidence* to test the hypotheses, the Thai shadow cases provide us with *across-case evidence* to substantiate and refine the hypotheses. The aim is to identify whether the Thai latecomers are progressing through similar stages as some Korean latecomers have done during their early years of late standardization. For the Thai cases, we adopt the same analytical framework as the one we use to analyze the Korean cases, although we know offhand that none of the Thai firms are now a world technology leader, let alone a standards leader. From our preliminary fieldwork in Thailand, we find that Thai latecomers are indeed standards followers with limited standards resources and capability and little involvement in standardization activities. Although the Thai latecomers cannot be used as an equal comparison to the successful Korean late standardizers, they provide insights into how other latecomers' experiences may be similar or different from those of Korean firms during their early stages of late standardization.

Industry focus: ICT (semiconductor and mobile telecommunications)

Our case studies focus on two information and communication technology (ICT) industries: the semiconductor and mobile telecommunication industries. There are three main reasons for selecting the two industries for the research.

First, as mentioned earlier, the ICT industry has, in recent decades, become one of the most important industries for many latecomer countries in their industrialization and economic development efforts. The importance of the ICT sector for a latecomer country, such as South Korea, is evident in its contribution to the country's economy. Semiconductors increasingly become an important commodity for the modern world economy and society, as they are the key components of many products that we use in our daily lives. The telecommunications industry has always been important, but its importance is even more pronounced now than before as the global economy moves towards information and knowledge-based economy. Mobile telecommunications services, in particular, are expanding exponentially in most countries around the globe. According to a market study by Portio Research (2005), the number of mobile subscribers worldwide grew to over two billion by the end of 2005, and is predicted to rise to four billion by 2011. In 2005 alone, there was an increase of 384 million subscribers from the start of the year. Meanwhile, the world population is likely to increase from approximately 6.5 billion to seven billion. This means that worldwide mobile phone penetration should pass the 50 percent mark by the end of 2009 (Portio Research 2005).

Second, while standards have always been important in other industries, they are particularly important for the ICT industry. ICT products tend to be more standards intensive, because of their systems and network characteristics. Both hardware and software of ICT products are interconnected. Reliable compatibility between them is crucial to their functioning. Theoretically, network characteristics of the ICT industry imply that first movers have tremendous advantages over second- or late-movers. In addition, not only does the number of standards in these sectors increase rapidly, many of them are revised and updated frequently as well. This means that it may be more difficult for late standardizers to catch up with forerunners in the ICT industries, such as semiconductor and telecommunications industries. Despite that, these are also the two industries in which some late standardizers not only have caught up with the forerunners from advanced economies, but also have forged ahead of them. For instance, several mobile telecom technologies developed by Samsung and LG have been incorporated into standards adopted by firms from advanced economies.

Finally, while the semiconductor and telecommunication industries share several common features, each industry has distinctive characteristics. The semiconductor industry is essentially a commodity business and is highly cyclical. Semiconductor companies face constant booms and busts in demand for products. Demand typically tracks end-market demand for personal computers, cell phones and other electronic equipment. On the other hand, for the telecommunication equipment industry, we can not be entirely sure whether the businesses are cyclical or not. The cross-industry differences allow us to examine whether our hypotheses hold true under different patterns of demand.

Table 1.1 displays the firms and standards institutions that we have selected for the case studies of the semiconductor and mobile telecommunications industries in South Korea and Thailand. As we adopt the prototypical-case-study approach, we have identified through our preliminary research some late standardizers that have developed from being standards followers to standards leaders. We base our selection on the level of standards resources and capability, the level of participation in external standardization, and the organizational structure for standards activities. In the semiconductor industry, the most "prototypical" case study of all is South Korea's Samsung Electronics. From our preliminary research, we find that Samsung Electronics is the most active latecomer firm in external standardization activities in the industry. South Korea's Hynix is another leading semiconductor firm with noticeable participation and contribution in standardization activities. Meanwhile, in the mobile telecommunications industry, Samsung Electronics, LG Electronics, and KT are among the very few latecomer firms that have recently exerted influence on international standardization of mobile telecom technologies. Because no Thai firms have significant participation and contribution in international standardization arenas, we have chosen firms that we think have devoted the most resources and have greatest capabilities among Thai firms in standardization activities in the semiconductor and telecommunication industries. With regards to non-firm institutions, we select them according to their level of involvement in standards activities in the semiconductor and mobile telecom industries.

Table 1.1: Firms and Institutions Selected for the Case Studies

Country	Industry	Firm	Domestic Institution	International Institution
South Korea (prototypical cases)	Semiconductor	Samsung Electronics; Hynix	KSIA; KATS	JEDEC
	Mobile Telecom	Samsung Electronics; LG Electronics; KT	KATS; TTA; MIC	3GPP; 3GPP2, APT; CJK Forum
Thailand (shadow cases)	Semiconductor	Hana Microelectornics	TISI; MTEC; NIMT	JEDEC
	Mobile Telecom	TOT; AIS	TISI; NECTEC	APT

The timeframe for the case studies covers the last three decades, i.e., from the early 1970s when South Korea started its late standardization efforts. We pay particular attention to the period since the early 1990s, when a few late standardizers started to become more visible in international arenas for technological standardization.

DATA COLLECTION

We collect the empirical evidence from four main sources: documentation, archival records, interviews, and direct observations (Yin 1994). Although most of the information we use in our case studies is from documents and interviews, archrival records and direct observations are sometimes useful in obtaining empirical evidence not available through the other sources. Documents include news articles, trade journals, meeting memoranda, company reports and brochures, and websites. Archival records include organizational and corporate records that show quantitative information about latecomer firms.

With regards to interviews, we have conducted semi-structured interviews with managers and engineers in different firms and standards organizations in the semiconductor and telecommunications industries, as well as government officers and researchers in standards institutions in South Korea and Thailand. We conducted most of the interviews in person, mainly in three locations at three separate times: (1) San Jose, California, at the JEDEX conference, in which all of major semiconductor firms participated in March 2005; (2) Seoul and its vicinity in April 2005; and (3) Bangkok in August 2005 and January 2006. These interviews were followed by telephone interviews, whenever they were considered necessary. Lastly, we conducted direct observations of latecomers' engagement in standardization activities during the JEDEX conference. We report the sources of information as appropriate throughout the dissertation.

SKIMMING THE SURFACE: THE MAIN FINDINGS

Our research is based on the assumption that late standardizers advance through distinct stages of technological development as they emerge as important players in the global markets. Unlike first- and late-movers from advanced economies, late standardizers need to overcome additional technological and resource constraints, as well as distance to lead-user markets and specialized inputs. They are "late" by necessity, not by choice. They enter the global market when there is already a dense thicket of standards, to which they have to subscribe. Yet, successful late standardizers manage to turn these seemingly formidable obstacles into opportunities for technological catch-up.

We thus examine whether late standardizers like late-industrializers also progress through distinct stages, and, if so, how these stages are related to technological catch-up. Our ultimate goal is to investigate how standards and related activities enable these firms to move from one stage to another, both in terms of technological development and competitive positions. We pay particular attention to four key aspects: (1) types and sources of standards and related activities that affect technological catch-up; (2) resources and capabilities for standards efforts; (3) organizational structure for standards activities; and (4) institutional arrangement and the role of the state that affect standards efforts.

We first concentrate our effort on building a staged model of late standardization and technological catch-up. Then, we examine the mechanisms for moving beyond each stage. As the main analytical framework, we build upon the concept of "resource leverage" as found in the strategic management literature (e.g., Ghoshal 1987; e.g., Hamel and Prahalad 1993) and expanded to explain late standardizers (Mathews 2002). Specifically, we focus on the two apparatus late standardizers utilize as a leverage mechanism to move beyond catch-up: namely, Linking and Learning. We examine these apparatus, using case studies of the semiconductor and mobile telecommunications industries in South Korea.

STANDARDS AS MECHANISMS FOR MOVING BEYOND AND AHEAD

The main argument of this study is that latecomer firms must engage in standards activities to progress beyond catch-up. Only when they engage in technical standardization can they move beyond catch-up, to keep up with technological change, to forge ahead of the forerunners, and to sustain technological leadership. In other words, standards and related activities propel latecomers to move from one stage of technological development to another.

Specifically, they have to engage internally in quality management and standardization to become fast followers. Quality standards are the key factor for latecomers to improve production processes, while enhancing credibility and reputation such that they become part of global value chains. Once they become fast followers, they have to participate in external standardization activities to improve ramp-up capability, the main source of their second-mover advantage. Once they manage to become technology leaders, these "late standardizers" have to lead standardization efforts, such that the standards leadership helps sustain their first-mover advantages derived from proprietary technologies and learning-curve effects.

Our argument is based on the observation that the extent of technological development is limited by the underlying standards. However much latecomers improve their technological capabilities, the extent of development is within the limits imposed by the standards they adopt. The proposition is particularly true in the standards-intensive industries, such as the ICT industry. Latecomers' technological catch-up efforts in these industries are thus very different from those in heavy industries, such as steel and automotive. In those manufacturing industries, latecomers have to overcome entry barriers due to economies of scale. In the ICT and other industries in which standards are essential, latecomers face entry barriers due to "economies of knowledge," which occur when a firm possesses and exploits internal stock of knowledge while other firms do not. Without engaging in standardization of new technologies, latecomer firms, such as Samsung Electronics, would not be able to move beyond being followers to forerunner firms from advanced economies, such as Intel and Sony.

Put differently, without increasing their standards capabilities and engaging in internal and external standardization activities, latecomers can never move beyond catch-up. As we discuss in detail in Chapter Four, standards capabilities include the capability to identify the needs for standards, to search and select appropriate standards, to acquire and assimilate standards into the production process, to adapt standards according to local conditions, to modify the standards in response to changing economic environments, and to develop new standards for internal use and then external use.

During each stage of late standardization and technological catch-up, latecomers derive competitive advantage from various sources. They capture different types of technological or entrepreneurial rents and rely on specific mechanisms to capture such rent.[4] Late standardizers concentrate their efforts on different types of standards and related activities during different stages of late standardization.

Engaging in quality standardization to move beyond catch-up

Specifically, during the catch-up stage, as late standardizers move from a latecomer position to a second-mover position, they concentrate their standards efforts on internal standards activities for quality and process control for production processes. The rationale is that their competitive advantage as latecomers rests mainly on cheap input factors. Because latecomers, by definition, have no cutting-edge technologies, they compete mostly in mature-product markets, in which firms compete on the basis of cost and quality, rather than value of the products. Especially for latecomers aiming to become an original equipment manufacturer (OEM), quality standards and tools are a crucial key to establishing the credibility and reputation, such that they can become part of global production and value chains.

Our case studies of Samsung Electronics and other Korean firms show that quality standards and tools, such as the ISO 9000 series and Six Sigma, are critical to latecomers' technological catch-up effort. They also develop and accumulate more sophisticated technical and organizational capabilities and resources for standards activities. As shown in our cases studies, Samsung Electronics and other successful late standardizers have significantly increased their resources devoted to external standards activities as they increase their technological capabilities.

Participating in external standardization to enhance ramp-up capability

As late standardizers improve their internal standards and technological capabilities, external standardization activities become more important as a source of competitive advantage. For fast followers, ramp-up capability is the key source of their second-mover advantage. Ramp-up capability concerns primarily with speed and volume in production. These two elements can be enhanced by the integration between product development and production processes. Quality standards and control, therefore, remain crucial at this stage of late standardization, as a tool to integrate product development and production.

However, implementing quality standards alone is not enough for enhancing ramp-up capability. What fast followers need is the knowledge about emerging technologies. They generally improve high-volume-production capability by relying on their knowledge about emerging technologies and their superb process technologies. Standardization activities enable them to improve both sources of ramp-up capability.

One important channel for latecomers' external standardization activities is to join "informal" standards consortia and alliances, in addition to formal standards organizations.

We argue that as late standardizers develop their technological capabilities, they have to be more involved in international standardization efforts, especially in "informal" standards consortia and alliances. Through their participation in standards forums, late standardizers create the leverage for their technological upgrading and market penetration in the world market. Some late standardizers are active followers, who learn about emerging technologies through standardization activities. Others are active participants in standards development, who provide technical inputs that become part of new standards.

Leading standardization efforts to sustain first-mover advantage

Once they have established a second-mover position, late standardizers engage in external standardization activities in order to keep up with rapid technological change and finally to move up to a first-mover position. While fast followers continue to improve their quality management and standardization, they also pay more attention to improving their capabilities for product design and development. Through various R&D efforts, many of them move closer to the world technological frontier and eventually become technology leaders themselves. A few of them become standards leaders, as they influence the directions of standards to reflect their strategic interests. Samsung Electronics and LG Electronics are now among standards leaders in several segments of the ICT industries. They focus more on "interface standards,"[5] which affect their strategic planning, and "transaction standards,"[6] which affect their market development. As fast followers, their competitive advantage depends on the ability to learn quickly what emerging products and technologies are, as well as the ability to ramp up their production. For fast followers, the ramp-up capability has already been accumulated during the catch-up period. Such capability is closely tied to the types of standards. Standardization activities on which fast followers focus, therefore, are not limited to production and quality control, but include external standards activities.

As first movers, late standardizers become even more active in leading and influencing standards development, so as to keep ahead of their competitors. The focus of their standardization efforts is on new-product specifications and functions. This is because their competitive advantage rests mainly upon the value, rather than costs, of the new products. Standards are an important means by which late standardizers strengthen their foothold as part of the "standards clubs" that determine the trajectories of future technologies and markets.

As late standardizers move closer to the world technological frontier, the mechanisms they use to appropriate standards-induced rents also change. As their technological and standards capabilities develop, intellectual property rights included in standards become more important as a mechanism to appropriate technological rents from their technological innovation. Specific channels for capturing such rents include cross-licensing agreements and standards-based patent pools. Patent pools allow holders of patents included in standards to cross-license each other without paying license fees. Patent-pool members can also receive royalties from other firms outside the pools that want to use the standards. A few successful late standardizers, such as South Korea's Samsung Electronics and LG Electronics, are already part of important patent pools for mobile communications technologies.

STANDARDS AS STRATEGIC LEVERAGE FOR LINKING AND LEARNING

As a leverage mechanism, standards enable late standardizers to manage the transitions through two basic apparatus: Linking and Learning. These apparatus allow late standardizers to overcome their unique constraints as latecomers, that is, inadequate resources and capabilities and limited access to lead-user markets and specialized inputs (Mathews 2002). By repeatedly using standards as Linking and Learning apparatus, late standardizers leverage their internal resources and capabilities for more knowledge and expertise available in the world market. We argue that standards are an integral part of what Mathews calls the strategy of "competitive complementarity," in which latecomer firms complement the strategies of incumbents, rather than competing against them.

As a Linking apparatus, standards connect latecomers with technological leaders in order to leverage their limited resources and capabilities. By adopting certain standards and technical specifications, either as part of outsourcing, second-sourcing, or OEM contracting, latecomers and fast followers establish external linkages with forerunners. Such external linkages allow latecomer firms to devote their resources to improving manufacturing processes, without having to invest in R&D for developing standards and specifications. Quality control and management standards facilitate the efforts by latecomers to improve their production and project execution capabilities. For instance, ISO 9000 quality standards allow firms to improve manufacturing and business processes.

By necessity, latecomers start by competing in markets with mature products and technologies. The basis of such competition is cost. Latecomers' competitive advantage is hence affected greatly by production costs and quality of products. Quality standards and standardization are, therefore, critical to their competitiveness. In fact, throughout the process of late standardization and technological catch-up, quality control and standardization is a key for latecomer firm to build a basic mechanism to move from one stage to another.

As a Learning apparatus, standards contain technological information, such as technical specifications, that latecomers firms can utilize without having to "reinvent the wheel." During the catch-up period, latecomers may learn about market characteristics and consumer preferences in advanced markets through standards and technical regulations. Through participation in standards development, fast followers learn about emerging technologies. They learn what technologies they should expect in the near future, even though they do not yet have proprietary technologies that they can contribute to standards development. Once they have established themselves as first movers, successful late standardizers acquire ideas about competitors' R&D and product development through external standardization activities.

For late standardizers who are already technological leaders, standards enable them to manage market and technological risks by forming standards alliances with other technological leaders – often their competitors – in the same industry. Advanced late standardizers, such as Samsung Electronics, participate in several standards consortia with other leading firms from advanced economies. Examples include the Joint Electron Device Engineering Council (JEDEC) in the semiconductor industry and the 3rd Generation Partnership Project (3GPP) in the mobile telecommunication industry. Standards also allow them to capture rents from the stock of proprietary intellectual property generated by their R&D efforts. A good example is the recent formation of patent pools to manage the Moving Picture Experts Group (MPEG) technologies, in which Samsung Electronics and LG Electronics are key partners.

Several exogenous factors affect the late standardization process of late standardizers, including the characteristics of the technologies, as well as the market structure. Shifting technological paradigms, for instance, open the windows of opportunity for late standardizers to catch up with forerunners. In order to capture the opportunities, late standardizers must have accumulated technological capabilities by adopting various R&D strategies. Although their engagement in standards efforts may appear in various forms and degrees, engagement in technical standardization is an essential strategy for latecomers to move beyond catch-up.

ORGANIZATIONAL LEARNING FOR LATE STANDARDIZATION

As late standardizers advance their technological capability, standards and related activities are given more attention by management and become an integral part of their R&D strategies. The increased importance can be manifested through organizational changes. As latecomers, standards-related activities are given an ad hoc status, with only a few engineers working on standards issues. However, as they move beyond catch-up towards keep-up and forge-ahead, specialized personnel and groups are assigned specifically to standards activities. Standards teams become a core component of R&D activities. Samsung Electronics, for instance, has established a Global Standards and Research Team within its Telecommunication R&D Center near Seoul. Similarly, LG Electronics has a team devoted to standards within its Mobile Telecommunication R&D Center also in the suburbs of Seoul.

Another indicator of increased importance given to standards is the change in human resource management to accommodate standards activities. As standardization activities in standards forums involve long-term commitment and personal connections, consistent and persistent participation is a critical factor. For instance, many technical experts that represent firms in JEDEC, a semiconductor standards forum, have been involved in its activities for many years, if not decades. Successful late standardizers, such as Samsung, have adjusted their internal job assignment and rotation practices for standards activities. The goal is to allow standards experts to continue working in the same department, while representing the firms in the same standards forums as long as possible.

CO-EVOLUTION OF INSITUTIONS AND TECHNOLOGIES

The role of the state in standards activities changes throughout the process of late standardization. Standards institutions co-evolve with technologies, as latecomer firms move closer towards the technological frontier. As they enhance technological and standards capabilities increase, late standardizers rely less on the state for developing and providing product standards. For instance, from our case study of South Korea, we find that the relevant ministries and governmental institutions, such as the Ministry of Information and Communication (MIC), become less directly involved in the standards development. Rather, non-governmental institutions, such as the Korean Telecommunication Technology Association (TTA), become more active in developing voluntary industry standards.

However, the role of the state remains crucial in the areas of non-product standards that function as "infratechnologies", such as measurement and reference standards. The more infrastructural the nature of a technical standard, a more active role of the state is required. Examples include basic measurement standards and reference materials for weight, time, and temperature. By deciding on certain infrastructural standards, the state can play a leading role in pushing the firms and other institutions to develop beyond catch-up. These infrastructural standards may also function as an institutional "boundary object" (Brown and Duguid 1998) to encourage mutual technical and organizational learning among latecomer firms and other institutions. A notable example is the successful collaboration between the Korean government, research institutions, and a few latecomer firms, including Samsung Electronics and LG Electronics, in adopting and developing the Code Division Multiple Access (CDMA) mobile technologies.

In addition, by setting up domestic institutional arrangements that correspond to the structure of international standards institutions, the state enables late-standardizing firms to benefit from such "institutional complementarity". The state also plays a significant role in creating linkages through "government-led networking" (Amsden and Chu 2003). This networking serves as the mechanism to align their differences in interests and goals, as well as resources and capabilities. Standards-related forums organized by the Korean government are good examples of such state-led networking.

The state also plays a crucial role in alleviating the risks for latecomer firms with regards to selecting the right technological trajectories and in securing initial market demand for the firms. The role of government research institutes, such as South Korea's Electronics and Telecommunications Research Institute (ETRI), are paramount. We demonstrate such critical roles of the state mainly through our case studies of the semiconductor and mobile communication industries in South Korea.

STRUCTURE OF THE STUDY

This study includes eight chapters. The argument we have put forth so far is fleshed out through subsequent chapters. In Chapter Two, we first review the basic concepts and characteristics of standards and standardization activities, as well as the literature on the relationships between standards and technological development. The review lays the foundation for our subsequent discussion in the dissertation. We then propose the staged model of late standardization and technological catch-up. In Chapter Three, we discuss the emergence of late standardizers in international standardization arenas. We present the empirical evidence that shows the participation of latecomer firms in technological standardization. We base our discussion primarily on the cases of Korean late standardizers in the semiconductor and mobile telecommunications industries. In Chapter Four, we discuss how standards enable late standardizers to move from one stage to another. We focus on the Learning and Linking apparatus that latecomers use as a strategic leverage to utilize their limited internal resources and capabilities. Chapters Five and Six present the case studies of late standardizers in the semiconductor and mobile telecommunications industries in South Korea and Thailand. In Chapter Seven, we turn our attention to the role of the state in late standardization process, particularly the co-evolution of standards institutions in late standardization processes. Chapter Eight is the conclusion of the dissertation.

CHAPTER TWO

LATE STANDARDIZATION AND TECHNOLOGICAL CATCH-UP

OVERVIEW OF STANDARDS AND STANDARDIZATION ■
STANDARDS AND TECHNOLOGICAL DEVELOPMENT ■ CATCH-UP AND LATE INDUSTRIALIZATION ■
A MODEL OF LATE STANDARDIZATION AND CATCH-UP ■ CONCLUDING REMARKS

The process of late standardization and technological catch-up is evolutionary, in that it is dynamic, path-dependent, and irrevocable.[7] We model a late standardizer as passing through a set of discrete positions, stages, events, and activities. In our model, the positions are the competitive positions through which a late standardizer progresses: latecomer, second-mover and first-mover positions. These competitive positions also correspond to the levels of technological development: latecomers are technology late adopters, second movers are fast followers, and first movers are technology leaders. The stages refer to the moves from one position to another. Late standardizers are modeled to pass through three stages, catch-up, keep-up, and forge-ahead. Catch-up occurs when latecomers attempt to become fast followers or second movers. Keep-up is when second movers aspire to close the gap from the world technological frontier and to become first movers. Finally, forge-ahead is when first movers maintain their leadership, not only in terms of competitiveness and technological innovation, but also in terms of standards and standardization.

In an evolutionary model, "events" trigger stages, which are the transitions from one position to another. In our model, events refer to the engagement in internal and external standards activities. In each of the three stages, late standardizers engage in different types of standards activities. With distinct sets of resources and capabilities, they participate in different types of standards forums and have different organizational structures for standards activities. Such activities include developing, adopting, maintaining, and adjusting standards.

This staged model serves as the foundation for our discussion in the following chapters on how successful late standardizers move from one stage to another. The model also lays the groundwork for our discussion in Chapter Seven as to how the roles of the state also change, as late standardizers develop towards the world technological frontier.

We start our discussion by reviewing the basic concepts and characteristics of standards and standardization. We then review two relevant strands of literature: one on the relationship between standards and technological development and the other on technological catch-up and late industrialization. We pay particular attention to the existing models of technological catch-up in the context of innovation dynamics and technology life cycle. We then offer our model of late standardization and technological catch-up, with a general description on standards activities in which late standardizers engage during each stage of the late standardization process. We will test the model with empirical evidence from the case studies of late standardizers in the semiconductor and telecommunications industries in South Korea and Thailand, discussed later in Chapters Five and Six.

OVERVIEW OF STANDARDS AND STANDARDIZATION

In this section, we give an overview of standards and standardization. We first review the definitions and functions of standards, then the economic characteristics of standards.

DEFINITIONS OF STANDARDS

Standards-development organizations, as well as analysts who study standards, define standards in many different ways. For instance, a standard is defined generally as an approved specification of a limited set of solutions to actual or potential matching problems (Vries 1999). It has to benefit the party or parties involved, while balancing their needs, and is intended to be used repeatedly or continuously by a number of parties for whom they are meant. According to Vries (1999), matching problems are problems of interrelated entities that do not harmonize with each other, while entities could be any concrete or abstract thing, including associations among these things, e.g., persons, objects, events, ideas, processes, etc. Standardization is thus the activity of establishing and recording standards.

A standard is defined more specifically as a specification or a set of specifications that describes the functions and/or features of a product, process, service, interface, or material (National Research Council 1995). The specifications may be technical or procedural. They may relate to size, weight, shape, design, function, or performance. They may relate to the way the product is labeled or packaged. Standards discussed in our study cover five different dimensions: namely, (1) standardization process; (2) compliance; (3) sources of standards; (4) elements for standardization; and (5) design or performance standards. We describe these dimensions in detail in the following section.

(1) Standardization process: de jure or de facto

The first dimension is the nature of the standardization process. Two types of standards are broadly classified as de facto and de jure standards (David and Greenstein 1990). De facto standards may arise *ex post* in the competitive markets, as a result of the uncoordinated interactions between firms. These standards are defined largely by consumers' preferences across the range of products provided by manufacturers. A particular set of product or process specifications is often considered a de facto standard when it obtains market share, such that it acquires authority. De facto standards may develop without formal sponsorship, as in the case of the QWERTY keyboard standard. They could also be developed by formal sponsorship, as firms promote their products or processes to maximize their technological assets (David 1985). The IBM-compatible personal computer system is a classic example for de facto standards with sponsorship. More recent examples of de facto standards with sponsorship include Microsoft's DOS operating system, Hewlett-Packard's Printer Control Language (PCL) for laser printers, and Adobe's PostScript page description language for laser printers.[8]

De jure standards, on the other hand, are developed *ex ante* either by government agencies, i.e., mandatory standards, or by standards organizations, i.e., voluntary industry standards. Mandatory standards are guidelines, rules, and regulations that are promulgated and enforced by government agencies. These include procurement standards for products supplied to government agencies, and regulatory standards that set criteria for safety, health, and environmental concerns. Voluntary industry standards, on the other hand, arise from coordinated processes in which participants in the market negotiate and seek consensus on product or process specifications. These standards are voluntary in that participants are not required to adopt them once the standards have been developed.

There are broadly two types of forums in which voluntary standards are developed: "formal" standards development organizations (SDOs), and "informal" standards consortia/coalitions. The degree of "formality" refers to the degree of government involvement in terms of recognition and enforcement (Krislov 1997). The most "informal" standards are those developed and used on an ad hoc basis for one or a few transactions among individuals. Then, there are prearranged standards used in contract exchanges. Less informal standards include prevailing tacit standards and prevailing articulated standards respectively. By this definition, standards that are developed by professional and expert groups, as in the case of voluntary industry standards are "informal". These standards become "formal" when they are recognized and/or enforced by the state. The most formal standards are those developed and enforced directly by the state.

Formal standards development organizations (SDOs) include those at the national level, such as the American National Standards Institute (ANSI), those at the regional level, such as the European Committee for Standardization (CEN), and those at the global level, such as the International Organization for Standardization (ISO). De jure standards developed by SDOs are usually the outcome of formal procedures based on the principles of openness, fairness, and consensus. The ISO 9000 series of standards, for instance, was the outcome of a long series of procedures and meetings among standards experts from different standards organizations from many different countries. The benefit of such standards is that, once developed, they may become the references for public procurements and the standard of choice among the supporters. Many governments have used such standards as a basis for national industrial policies. For instance, the Korean government has developed and enforced quality standards for products to be exported to the world market. One objective is to improve the image about Korean products among overseas consumers. We will discuss this issue in detail in Chapter Seven on the roles of the state.

The second type of standards forums is "informal" consortia, which are groups of firms that aim to create specifications on a particular topic or technology. In recent years, an increasing number of standards have been developed by consortia. Some of these "specifications clubs" were formed to oppose another technical effort, to initiate or complete an offering, or to make tested profiles possible and available. Consortia increasingly become the forums for standards development in industries with fast-changing technologies. Compared with formal standards organizations, consortia generally issue standards at a faster pace. Their standards often lead to specifications that reflect the market needs and usually have at least one implementation. While these standards could eventually become industry standards, they are developed outside formal SDOs and thus do not follow as strict rules and procedures as formal de jure standards. (Cargill 2001)

Consortium standards are more likely to be implemented than standards developed by formal SDOs, due to two main reasons (Cargill 2001). First, technical task forces and working groups in consortia are more likely to proceed according to their mandated schedules. Because consortia participants have a vested interest in producing standards, their level of commitment to the successful development of standards is greater than those participating in formal SDOs. The second advantage of consortia is their ability to set up and run tests for implementation of their specifications. Because of the contractual arrangement with participants, many consortia are able to compel their members to adopt and implement their standards and specifications in preference to other standards. This means consortium standards are more likely to be quickly adopted by the market than SDO standards.

(2) Compliance: mandatory or voluntary

Standards can also be defined in terms of compliance. As described earlier, de facto standards are voluntary in that firms are not forced by regulations or laws to adopt them. The same is true for voluntary industry standards developed by SDOs. However, standards could become mandatory once they are enforced by governments and/or mandated by laws.

This taxonomy applies to both national and international levels. In the Agreement of Technical Barriers to Trade (TBT) of the World Trade Organization (WTO), a standard is defined as a "document approved by a recognized body, which provides, for common and repeated use, rules, guidelines or characteristics for products and processes, with which compliance is not mandatory. It may also include or deal exclusively with terminology, symbols, packaging, marking or labeling requirements as they apply to a product, process or production method." (TBT, Annex 1)

According to the TBT Agreement, technical regulations are distinguished from standards. A technical regulation is defined as "document which lays down product characteristics or their related processes and production methods, including the applicable administrative provision, with which compliance is mandatory. It may also include or deal exclusively with terminology, symbols, packaging, marking or labeling requirements as they apply to a product, process or production method." (TBT, Annex 1) The main difference between standards and technical regulations thus lies in the required degree of compliance.

(3) Sources: internal or external to firm; domestic, foreign, or international

From a firm's perspective, there are five main sources of standards. The first source is within the firm itself. Firms may develop their own standards for internal uses, although this is unlikely for most latecomer firms, which do not have advanced standards capabilities. The second source of standards is other firms that have developed de facto standards. This source could be domestic or foreign. The third source of standards is domestic standards development organizations (SDOs) and other industry consortiums that may develop standards for domestic uses. The fourth is international SDOs, such as the ISO and the International Telecommunication Union (ITU). Last but not least, another main source of standards is foreign SDOs, especially those in developed countries that are active in generating standards, such as the American National Standards Institute (ANSI). Firms may acquire standards through various modes, including direct purchase from domestic, foreign, or international SDOs. They can also acquire standards through suppliers and/or buyers. (United Nations 1964; Sharpston 1969; Vries 1999)

(4) Elements: product-element or non-product element

Standards can be categorized by the elements subject to standardization. Product standards specify the characteristics of goods, including physical dimensions and specifications, performance requirements, and compatibility with other components. Process standards refer to the conditions and procedures under which products are made. These include conditions related to products themselves, such as a chemical formulation or rules of production for wines within certain regions. They may even include broader conditions that are not directly related to the final products, such as working conditions. Labeling requirements may also be considered standards, as they require that producers provide consumers with the information on product characteristics and/or production conditions (Stephenson 1997).

(5) Design or performance

Standards can be specified in terms of design specifications as in design standards or performance levels as in performance standards. Design standards specify exactly what elements or dimensions need to be followed. Performance standards, on the other hand, specify what the levels a product or element has to perform. Design standards are also more restrictive and may inhibit innovation to a greater extent than performance standards (e.g., National Research Council 1995; e.g., Tassey 2000). With performance standards, firms still have the flexibility in designing products or services, leading to innovative solutions to production problems.[9]

FUNCTIONS OF STANDARDS

Standards have important implications for firms in at least six important ways (National Research Council 1995). First, standards facilitate economic transactions. As standards are specifications that define the functions and/or features of a product or process, buyers and sellers can communicate consistently about the basic elements of the product or process in question. Standards thus play a fundamental role in conveying technical information about certain products and processes, reducing the transaction costs for the buyer and seller. In other words, standards serve as institutions that form the basis for economic transactions.

Second, standards play a critical role in defining the interfaces between products that are used together. In other words, standards ensure compatibility between various products and/or product components in a system. Recent technological innovation and diffusion in computer, telecommunications, and consumer electronics have further raised the importance of compatibility standards. They allow producers and users to benefit from network externalities arising from the interconnected systems of hardware and software (Katz and Shapiro 1986).

The third and fourth functions of standards concern production processes and management. Manufactures can improve production efficiency and benefit from additional economies of scale in production by standardizing parts, components, and production processes. They can improve their process management by adopting process standards, such as ISO 9000 series and Total Quality Management (TQM). These standards help manufacturers improve production processes by setting up and maintaining a quality assurance management system. Standardization is indeed the basis for quality control of raw materials, of production processes, and of final products.

Fifth, from the consumer's standpoint, standards increase the efficiency of product selection, as products that conform to the same standards can be easily compared. This effectively increases the competition among producers. However, there is a potential for excessive standardization, in which consumers have limited range of products to choose from.

Sixth, many standards serve as a mechanism for enhancing social welfare, such as protection of health, safety, and the environment. These types of regulatory standards or technical regulations are usually administered by government agencies at various levels. Finally, standards help reduce the variety of a generic product and/or technology to increase the economies of scale. We will discuss this function of standards in detail when reviewing the relationship between standards and technological development.

ECONOMIC CHARACTERISTICS OF STANDARDS

In order to understand how standards affect latecomers' technological development and catch-up, we first need to understand their basic economic characteristics. There are two properties of standards that are particularly relevant to this study: (1) public-goods properties and (2) network externalities.

Standards as public, private, or club goods

Standards can be analyzed in terms of public goods. Standards of measurement, such as linear, weight, bulk, temperature, and time, are public goods. Once they are created, anyone can use them, but the use does not reduce the amount available to others. In other words, standards of measurement are non-excludable and non-rival (Kindleberger 1983).

Although standards generally have some public-goods content, not all standards are purely public goods. Some standards are used within firms and organizations, while some are privately developed and used by manufacturers of industrial goods. The latter of these types of standards are private goods rather than public goods. In many instances, standards are developed by private entities but then become more widely used by the public. One example is the Kanban system, a signaling system developed by Toyota, the Japanese automobile maker, as a means to manage the Just-In-Time (JIT) production system (Sugimori et al. 1977).

If the property rights for standards could be defined, the rents generated by standards could be privately appropriated. Some standards are collectively developed by a number of firms, who may or may not license to other firms the proprietary technologies included in the standards. This makes the standards more like club goods, in that they are jointly produced, consumed, and benefited by a group of entities (Casella 2001). In this case, the goods are excludable, but not rival. Characteristics of club goods depend on preferences, endowments, and technological possibilities and constraints. This means standards could differ across locations and change over time.

Most standards rely on non-product technology elements, such as interface protocols, measurement and test methodologies, reference materials, and technical databases. These technological elements are generally more difficult and expensive for individual firms to make proprietary. The state thus assumes the role in providing the so-called infratechnologies that serve as the basis for standards. (Tassey 2000)

Network characteristics of standards

Another characteristic of standards is its potential to increase network externalities, also known as network effects or bandwagon effects. Direct network effects are formally defined as the marginal change in the utility of a product for a consumer as the number of consumers increase (Katz and Shapiro 1986). Network effects are external demand-side scale economies, in which each consumer enjoys more benefits as more people consume the same products that are connected.[10] A classic example is fax machines. As more people use fax machines, every fax machine becomes more valuable as the user has greater use for it.

In addition to direct networks effects of the connected products, consumers may also benefit from indirect network effects, or complementary bandwagon effects, due to the supply of complementary products from independent vendors. For instance, a consumer can benefit more from a product, such as hardware, when there are more complementary products, such as software, supplied in the market (Rohlfs 2001). These network externalities induced by standards have important implications for manufacturers.

Standards, particularly those for compatibility and interoperability, generally increase the network effects of the components, elements, or products that are used together. Depending on the type of a standard, it could increase either the direct or indirect network effects, or both. Standards thus have important implications for firms at least in two ways. First, standards could create pools of labor with user skills, which may reinforce the tendency to stick with certain standards. Second, standards could increase switching costs on the part of the users, as they accumulate standards-specific assets, such as equipment, software, and skills. Because of the high switching costs, standards could potentially create lock-in situations. The network effects of standards lead many firms to adopt business strategies that aim to capture a large market share before their competitors. (Shapiro and Varian 1999; Rohlfs 2001)

STANDARDS AND TECHNOLOGICAL DEVELOPMENT

The relationships between standards and technological development have been examined from mainly three approaches. The first approach is within the framework of neo-classical economics, examining the production and consumption of standards. Some analysts focus on the producer side, studying the strategic interactions between firms regarding standardization strategies for products in network industries (e.g., Farrell and Saloner 1985; Katz and Shapiro

1986). Other analysts focus on the user side, paying attention to the costs and benefits of variety reduction due to standardization (e.g., Farrell and Saloner 1986).

Analysts using the second approach focus on the institutional and organizational aspects of standards and standardization activities (e.g., Schmidt and Werle 1998). This approach includes a number of case studies of standardization organizations that are analyzed within the Social Construction of Technology (SCOT) framework (Bijker et al. 1987; Bijker 1995). The institutional aspects have also been evaluated by an increasing number of case studies of standardization organizations (e.g., Schmidt and Werle 1998; Loya and Boli 1999; Werle 2001). A few of these studies deal with governance and political issues of international standardization (Krasner 1991; e.g., Mattli 2001; Mattli and Buthe 2003; Drezner 2004).

Analysts using the third approach work within the framework of evolutionary economics. From this perspective, standards and technological innovation have a symbiotic relationship with each other, co-evolving at both firm and industry levels (e.g., Metcalfe and Miles 1994). In many respects, this is the theoretical paradigm that governs our research. As mentioned earlier, the aim of our research is to describe and explain the process of late-standardization and technological catch-up of latecomers. The evolutionary framework is thus appropriate for us to adopt in examining the process of late standardization and technological catch-up.

According to Witt (2002), an evolutionary theory has to possess three properties. It has to be: (i) dynamic, such that the dynamics of the processes can be represented; (ii) historical, in that it deals with historical processes that are irrevocable and path-dependent; and (iii) self-transformation explaining, in that it includes hypotheses relating to the source and driving force of the self-transformation of the system.

By definition, technological catch-up processes are dynamic and historical. Although the terms irrevocability and path-dependency are subject to interpretation, we assume that, even though certain patterns may recur in the historical process, the process does not repeat itself identically and, therefore, it is "irrevocable" (Witt 2002). Although innovation often leads to the development of standards, standards themselves affect the way in which technology evolves. Standards serve as a coordinating mechanism for technological development. Effects of standards on technological change occur through three main channels, namely (1) variety reduction, (2) codification of knowledge, and (3) compatibility/ interoperability (David and Greenstein 1990; Antonelli 1994; Blind 2004). We discuss these channels in turn.

(1) Variety Reduction

The first channel through which standards may affect technological change is its variety-reduction mechanism at the levels of the firm, the industry, and the entire economy. In the process of standards development, variations of products and technologies are selected and reduced to certain numbers that are deemed appropriate for standardization. When standards set the specifications of a product, regarding its design, quality, or interface, any attempt to produce alternative designs is likely to incur additional costs and time (Blind 2004). This could affect the rate of technological change, for which the existence of variety is a prerequisite. Standardization normally occurs when the technology is still immature. Variety reduction at the early stage may negatively affect technological change by reducing possible product variations that could become the basis for further product development.

Yet, standards produce positive effects on technological change to counterbalance the negative ones. This relationship between standards and technological change can be understood in an evolutionary framework, within which the tension between uniformity and variety occurs in the process of technical change and development (Metcalfe and Miles 1994). From an evolutionary perspective, technological progress does not occur in a random, non-cumulative manner, but happens within the paths and directions found to be productive. Standards help achieve this by reducing the complexity in combining knowledge for generating new innovations. They thus contribute to technological development by channeling technological efforts towards the fruitful directions. Standards also increase potential for the selected products or technologies to gain economies of scale, which further leads to reduced costs and prices and large customer bases. They allow firms to focus their research and development (R&D) on a smaller number of product and technical options. This reduces the risks inherent in R&D efforts and fosters technological progress. (Metcalfe and Miles 1994)

(2) CODIFICATION AND TRANSMISSION OF KNOWLEDGE

Standards may affect the rate in which technological variety is produced within a technological paradigm or a dominant design (Antonelli 1994). The imposition of uniformity in the form of standards permits the efficient replication and diffusion of technological knowledge. Because standards function as carriers of information about products and processes, they play an important role in the process of technological diffusion. When an innovation developed by a firm or a group of firms becomes an industry standard, other firms can benefit by adopting that standard without having to explore all possible options from scratch or reinventing technologies already developed elsewhere. Standardization makes it possible for firms without advanced technologies, generally those in developing economies, to enter the market by imitating standardized products (Stephenson 1997).

The process of technological diffusion through standards can also be analyzed in terms of knowledge spillover. Standardization processes are, in effect, the processes of codifying some of the tacit and uncodified knowledge embodied in products and processes. Especially in the case of de jure standardization, firms and individuals that participate in the process have to cooperate and share some of their proprietary information and knowledge. Standards thus convert tacit, localized, and proprietary knowledge into generic, explicit technological and organizational knowledge that other firms can utilize (Antonelli 1994).

COMPATIBILITY AND INTEROPERABILITY

Compatibility standards can also affect technological change significantly. Analysts have shown how compatibility standards affect the rate of technological progress and/or the time when products are introduced to the market. For instance, Katz and Shapiro (1992) model a situation in which one of the two competing products has been introduced, and the second firm has to decide on the timing of product introduction and its compatibility with the existing product. They show that the second firm is generally biased against compatibility, as its expected utility is to be greater when the two products are not compatible. Regibeau and Rockett (1996) analyze this issue in a different setting, in which neither of the two competitors has introduced a product. They find that compatibility accelerates the timing of introducing the first product, but further delays the introduction of the second product.

In sum, as standards define both the general concept of technology systems and the design configurations, they affect both the generation and the limitation of innovation and technological diffusion. By reducing technological uncertainty, standards guide the pattern of technological change in fruitful directions, while permitting variations therein. Standards may also affect the timing of product introduction, which, in turn, determines the rate of innovation.

EMPIRICAL LITERATURE

Although there is substantial theoretical literature on the relationships between standards and technological development, the empirical literature is much smaller. Most empirical studies examine certain standards in certain products and/or industries. Examples include standards for spreadsheet software (e.g., Swann and Shurmer 1994), for mobile telecommunications (e.g., Schmidt and Werle 1998; e.g., Pelkmans 2001), for the broadcasting industry (e.g., Besen and Johnson 1986), among many others.[11] However, most studies focus on standards development processes and the selection of technologies for standards. We know little empirically how standards affect technological change in the long run and how standards affect the production techniques and methods at the firm level.

TECHNOLOGICAL CATCH-UP AND LATE INDUSTRIALIZATION

As mentioned earlier, the main focus of our study is on the dynamics of late standardization process in the context of technological catch-up. The most relevant literature that serves as the foundation for our study is one on technological catch-up and late industrialization. In this section, we first briefly review the literature on technological catch-up, as summarized in Table 2.2. We then review three specific models that we use as the starting point for our model of late standardization.

TECHNOLOGICAL CATCH-UP AND LATE INDUSTRIALIZATION

There is now substantial literature on technological catch-up and late industrialization. This includes the pioneer contributions of Veblen (1915) and Gerschenkron (1962), who focus on the European catch-up prior to the First World War. Their analyses shed light on the roles of policy and institutions in Germany and other continental European countries in catching up with Britain. One main argument of this version of the catch-up hypothesis is that the more backward a country is in technological development, the faster it is likely to catch up with the forerunners. The explanation for this hypothesis is related to the technology embodied in a country's capital stock. Latecomers may be able to gain higher productivity growth than forerunners, as their new capital stocks embodied new technologies and knowledge. According to Gerschenkron, a successful catch-up requires that the latecomer target progressive and dynamic industries and invest in the most modern equipment and facilities. A critical element of the catch-up process is a set of institutional instruments that would mobilize resources to undertake the necessarily large investment at the plant level.

Another subset of catch-up authors, which we classify under the development-state approach, focus on the post-Second World War cases of late industrialization, such as Japan (e.g., Johnson 1982), Korea (e.g., Amsden 1989), and Taiwan (e.g., Wade 1990). Similar to Gerschenkron's argument, these authors stress the role of latecomer governments in targeting progressive, dynamic industries that require large investments. Through pro-active fiscal, industrial and trade policies, latecomer states pursued the development of targeted industries. Although these analysts focus on the roles of developmental states in successful late industrialization, they highlight different aspects of the catch-up processes. While Amsden

(1989; 2001) stresses the roles of large business groups in latecomers' technological catch-up efforts, Wade (1990) pays less attention to technology but more to the disciplinary roles of the state in governing the market. One distinction between this set of authors and Veblen/Gerschenkron is that they stress the crucial role of export markets in the catch-up effort of East Asian late industrializers.

The third set of authors on catch-up is led by the work of Abramovitz (1986) who conducts a macro-level analysis to examine long-run, cross-country data on economic growth and the factors that affect catch-up and convergence. According to Abramovitz, the catch-up processes depend on two groups of factors: technological congruence and social capability. Technological congruence refers to the factors, such as market and resource constraints, that prevent a country from effectively utilizing certain technologies, while others are able to, with equal access to the same technologies. Social capability refers to general features of national systems that latecomers need to develop, including educational, infrastructure, financial, and political systems.

Another contribution to the literature on technological catch-up is that of Perez and Soete (1988). Their main argument is that during the early stages of techno-economic paradigms, entry barriers are relatively low and knowledge is more publicly available for latecomers to utilize. The shifting paradigms thus create windows of opportunity for latecomer countries to enter the new technological systems and eventually the new markets. For latecomers to capture the windows of opportunity, they need to have the requisite technological capability, which includes the ability to predict technological trajectories and the ability to identify their competitive advantages vis-à-vis the forerunners and other latecomers. One criticism of this argument, however, is that it remains unclear as to how latecomers can actually capture the opportunity. In Table 2.1, we summarize the different sets of authors and the main factors distinguishing their studies.

Table 2.1: Comparison of Studies on Technological Catch-Up

Studies	Methodological approach	Main Focus	Main hypotheses regarding catch-up	Industries in which catch-up takes place	Technological Conditions	Central concepts
Abramovitz (1986)	Aggregate approach (comparison across a large group of countries)	Internal conditions	Inverse relation between initial levels of economic development and its growth rates across countries	Overall economy (labor productivity, income level)	-	Technological congruence and social capability constitute potential for catching up
Gerchenkron (1962)	Disaggregate approach (individual or a small group of latecomers)	Internal conditions	Latecomers could catch up with forerunners by undertaking more capital-intensive investment	Heavy industries	Technological trends moving towards increasing capital intensity	Roles of institutions in mobilizing resources
Perez & Soete (1988)	Disaggregate	External conditions	Technological development is a cumulative and continuous process within a techno-economic paradigm, but a discontinuous process across paradigms. Catch-up can occur during the shifts of paradigms	General	Systemization of technologies	Latecomers gain advantages when technological paradigms change, and are able to catch up and forge ahead of forerunners.
Amsden (2001)	Disaggregate	Internal conditions	The later a country industrializes, the more dominant foreign ownership	Heavy industries, textiles, electronics	Shorter product life cycle	Roles of the developmental state and large business groups in catch-up
This study	Disaggregate	Standards	Latecomers could catch-up with, keep up with, and finally forge ahead of, forerunners only by undertaking standardization efforts	Information technology (semiconductor and telecom)	Technological trends moving towards increasing network intensity	Stage model of late standardization

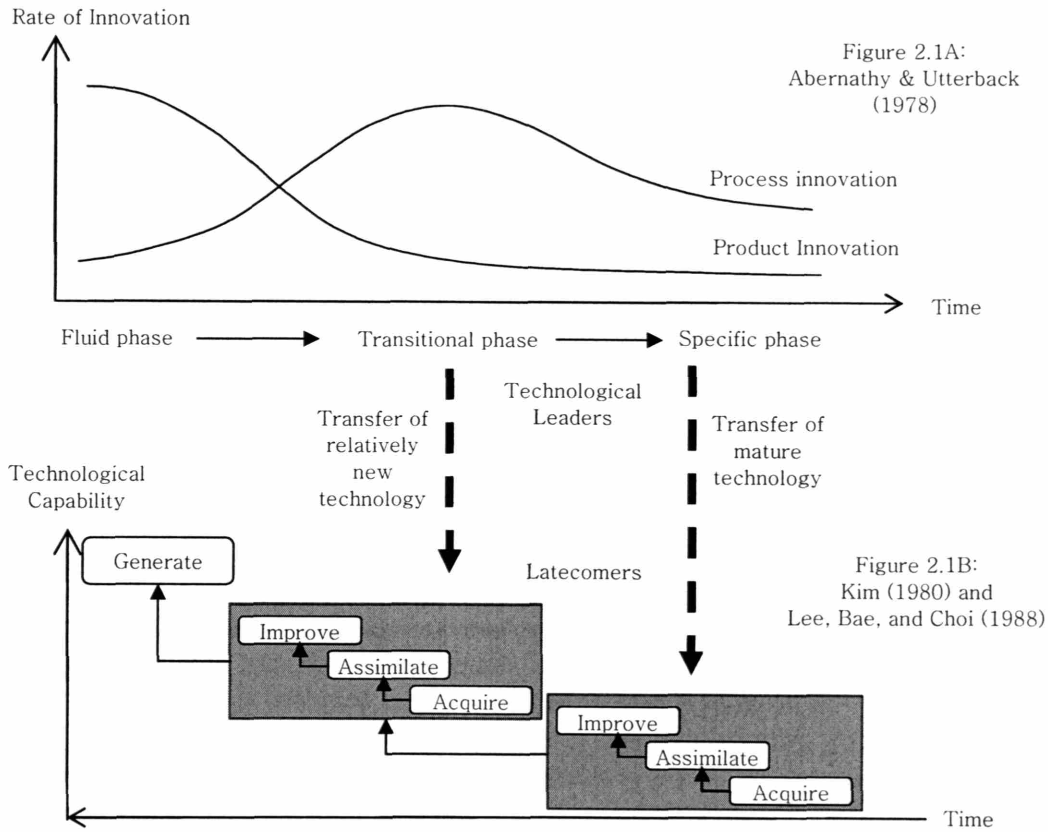
Although these analysts have contributed greatly to the understanding of the catch-up processes, none of them have analyzed an important aspect of industrialization, i.e., standardization. From their analyses, a reader can learn little about how latecomers deal with different types and levels of technical standards and related activities, how technical standards affect their technological development and competitiveness, and how some of them have managed to move beyond being standards followers to becoming standards leaders at the world technological frontier. These issues have yet to be assessed systematically using primary empirical research.

MODELS OF TECHNOLOGICAL DEVELOPMENT AND CATCH-UP

Many existing models of technological catch-up are staged models. The assumption underlying a staged model is that there is a series of discrete stages over time, each of which constitutes different activities, capabilities, competitive positions, organizational structures, and so on. While firms in reality are diverse and evolve along different paths, staged models allow us to understand conceptually the evolutionary process over time. The criteria for dividing a staged model could be developed from the existing models in the literature, or by observing the actual cases.

The proposed model of late standardization and technological catch-up is also a staged model. It combines elements from three existing models of technological development and catch-up: that is, (1) Abernathy and Utterback (1978)'s dynamic model of innovation; (2) Linsu Kim (1980; 1997)'s staged model of technological development; and (3) Lee, Bae, and Choi (1988)'s model of technological development processes. Figure 2.1 summarizes the relationship between the dynamics of innovation and technological catch-up by latecomer firms described as in the three models.

Figure 2.1: Dynamics of Innovation and Technological Catch-Up



Abernathy-Utterback's dynamic model of innovation

Our starting point is the innovation dynamics model by Abernathy and Utterback. They hypothesize that the rate of major innovation for both products and processes follows a general pattern over time. As Figure 2.1A indicates, the rate of product innovation in an industry or a product class is the greatest during its early period. During this so-called "Fluid Phase," experimentation with product design and operational characteristics results in a large number of product innovations. Firms give much less attention to the processes by which products are made.

The period of fluidity is generally followed by the "Transitional Phase" in which the rate of product innovation decreases while the rate of process innovation increases. During this period, product variety is replaced by designs that have become de facto standards of the industry as dictated by the market, or designs that have been dictated by accepted industry protocols or regulations. As the "dominant designs" are settled, producers are able to manufacture their products more quickly. More attention is given to process innovation.

Finally, the industry or product class enters the "Specific Phase." The rates of innovation for both products and processes decrease. Firms shift their focus onto cost, volume, and capacity, rather than on product and process innovation. In our case studies, the semiconductor industry has arguably passed its Fluid and early Transitional Phases. As semiconductors are now being commoditized, the industry is arguably approaching the Specific Phase of the Abernathy-Utterback model. The mobile telecommunications industry, on the other hand, is probably in the Transitional Phase. Table 2.2 summarizes the main characteristics in the three phases of innovation dynamics.

Table 2.2: Main Characteristics in the Three Phases of Innovation Dynamics

	Fluid Phase	Transition Phase	Specific Phase
Innovation	Frequent major product changes	Frequent major process changes induced by rising demand	Incremental for products and with cumulative improvements in productivity and quality
Source of innovation	Industry pioneers; product users	Manufacturers; users	Often suppliers
Products	Diverse, customized designs	Stable, dominant designs with significant production volume	Mostly undifferentiated, standard products
Production processes	Flexible and inefficient, major changes easily accommodated	Becoming more rigid, with changes occurring in major steps	Efficient, capital intensive, and rigid
R&D	Focus unspecified because of great technical uncertainty	Focus on specific product features once dominant design emerges	Focus on incremental product technologies; emphasis on process technologies
Equipment	General purpose, requiring skilled labor	Some sub-processes automated	Special purpose, mostly automatic, with labor focused on tending and monitoring equipment
Plant	Small-scale, locating near users or sources of innovation	General-purpose with specialized sections	Large-scale, highly specific to particular products
Cost of process change	Low	Moderate	High
Competitors	Few, but growing in numbers with fluctuating market shares	Many, but declining in numbers after emergence of dominant design	Few, classic oligopoly with stable market shares
Basis of competition	Functional product performance	Product variation; fitness for use	Price
Organizational control	Informal and entrepreneurial	Through projects and task groups	Structure, rules, and goals
Vulnerabilities of industry leaders	To imitators, patent challenges, and successful product breakthroughs	To more efficient and higher-quality producers	To technological innovations that present superior product substitutes

Source: Utterback (1994)

Linsu Kim's and Lee, Bae and Choi's models of technological development

In Linsu Kim's model of technological development, latecomer firms develop technologically through three distinct stages, namely, (1) acquisition and implementation (2) assimilation, and (3) improvement of imported foreign technology. During the first stage, latecomer firms import relatively mature technologies from technological leaders in industrialized countries. By implementing these technologies, they accumulate knowledge and know-how in product design and production operation. These experiences provide the basis for the second stage of technological development in which latecomers gradually improve indigenous capability to assimilate imported technologies. Finally, latecomers enter the third stage when they slowly but surely improve foreign technologies for new products and production processes. Driven by increased competition in domestic and international markets, latecomers upgrade their indigenous technological capability through efforts to assimilate foreign technologies by focusing more on R&D. Linsu Kim has shown that this staged pattern is evident not only in the history of manufacturing industries in Korea but also in other countries.

Lee, Bae, and Choi extend this model by relating it to the Abernathy-Utterback model of dynamics of innovation. The main idea of the extended model is that latecomers start their catch-up process by first adopting and assimilating mature technologies developed by technological leaders. This corresponds to the Specific Stage in the Abernathy-Utterback model in which the rate of product innovation is already low and product designs have matured. Competition at this stage is based on incremental-process innovation rather than product innovation. As latecomers accumulate their technological capability, they are able to compete against the leaders with production-related technologies that are indigenously improved and developed. Once latecomers reach the advanced stage, they are able to generate their own product innovations and design concepts. At this stage, latecomers have caught up with the existing leaders, and compete against them in new technological fields in the Fluid Phase of the Abernathy-Utterback model.

A MODEL OF LATE STANDARDIZATION AND TECHNOLOGICAL CATCH-UP

Combining the key elements from the three models above, we propose a model of late standardization and technological catch-up. In building the model, we consider several factors related to standards and standardization, including (1) standards capability at the firm/industry/national levels, (2) participation in standards forums, (3) internal organizational structure for standards activities; (4) competitive positions and environment, and (5) roles of the state. Based on the empirical analysis of latecomer firms in South Korea and Thailand, we divide the process of late standardization and technological catch-up into three stages, according to its relationship with the dynamics and technological catch-up process of latecomer firms and their competitive positions.

We categorize firms into three groups, according to the level of technological development. The first group is *late adopters or latecomers*, which are firms that operate mostly within the domain of the Specific Phase in the Abernathy-Utterback model. The second is *fast followers*, that is, firms in the Transition Phase. The third group is *forerunners* or *technology leaders* that operate mainly in the Fluid Phase of the innovation dynamics model.

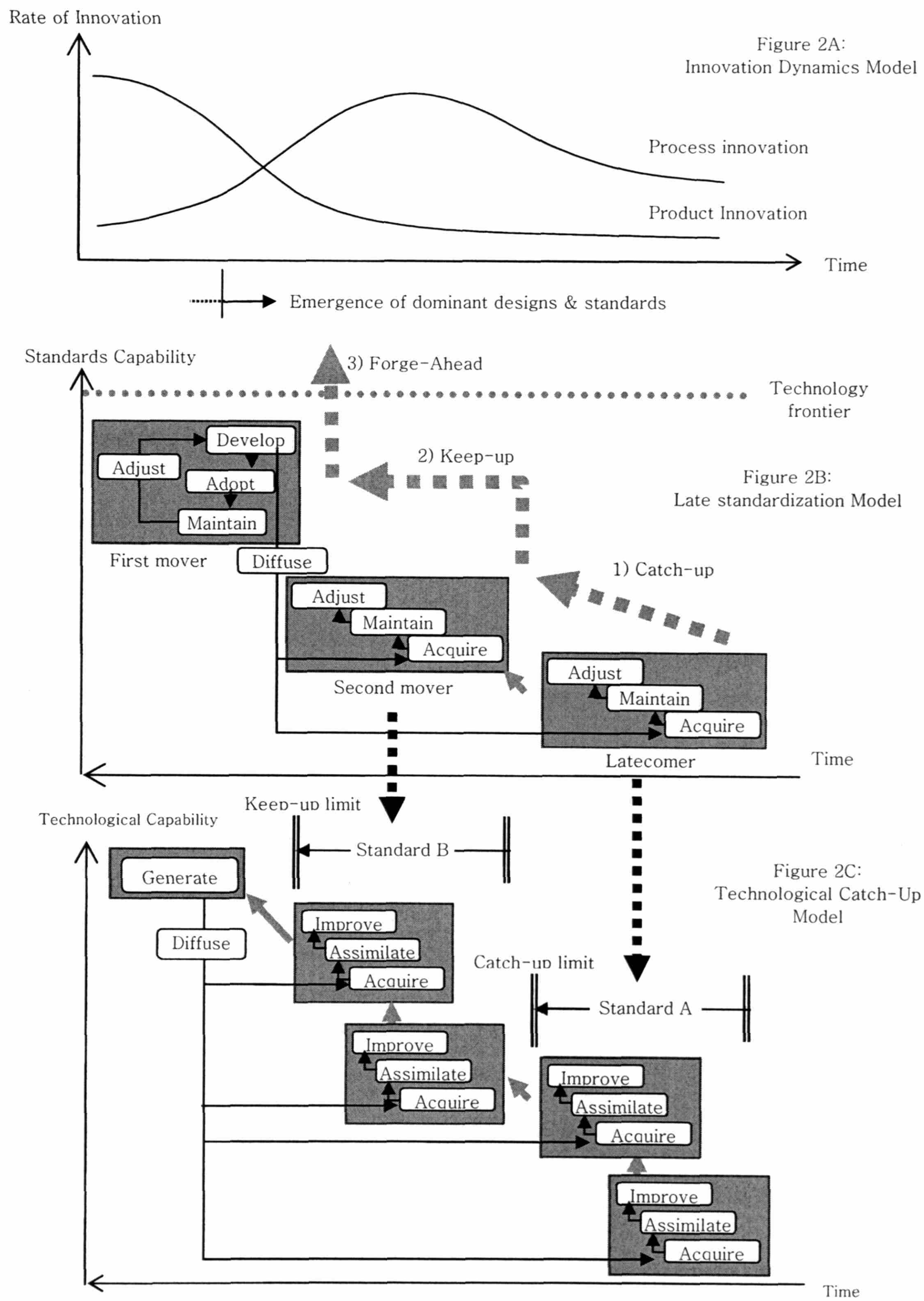
We can also think of these three groups of firms in terms of competitive positions and order of market entry. Forerunners are first movers, while fast followers are second movers or late movers. Latecomers are not just late movers but also face additional difficulties in terms of market access and availability of specialized skills and other production factors. Although forerunner or first-mover firms may have products and services with various degrees of technological maturity, the main difference between them and fast followers, not to mention latecomers, is that they have strategic options and capabilities to choose which products at what levels of technological maturity to focus on.

In the process of late standardization and technological catch-up, successful late standardizers progress through the three distinct stages before they reach the point where they become a standards leader at the technological frontier. They progress initially from the latecomer position where they are constrained in terms of resources, capabilities, and market access, finally to the first-mover position where they exploit their technology and other proprietary assets. Put differently, they move from the situation in which their market entry is late by necessity to the situation in which they can choose either to be an early- or a late mover.

The three stages of late standardization are: (1) catch-up, (2) keep-up, and (3) forge-ahead. The first stage of catch-up occurs when late standardizers attempt to overcome latecomers' unique constraints, such that they become fast followers or second movers. As they become fast followers, late standardizers establish themselves as key players in mature product markets. The second stage of keep-up refers to the process in which second movers attempt to become first movers. They aspire to close the gap from the technological frontier. Finally, the forge-ahead stage is when first movers maintain their leadership, not only in terms of market share and technological capability, but also in terms of standards capability.

As shown in Figure 2.2, the process of late standardization corresponds to Abernathy-Utterback's innovation dynamics (Figure 2.2A) and Linsu Kim's and Lee et al.'s models of technological catch-up processes (Figure 2.2C). The proposed model of late standardization (Figure 2.2B) shows that latecomer firms progress through three distinct stages of late standardization. They start from the first stage of catch-up, then move onto the second stage of keep-up, and onto the third stage of forge-ahead. The three stages apply not only to latecomer firms but include institutions and governments in latecomer countries. At this level of focus, the unit of analysis could be a country, an industry, or a firm.

Figure 2.2: Late Standardization and Technological Catch-Up



During different stages of late standardization and technological catch-up, late standardizers not only occupy different competitive positions in the market, but also engage in different types of standards activities. They possess distinct sets of standards resources and capabilities, participate in different standards forums, and have different organizational structures related to standards. The roles of the state are distinct in different stages. In Table 2.3, we summarize the relationships between each of the three stages of late standardization and the corresponding standards activities, capabilities, and organizational structures. In the following section, we discuss the specific activities in which firms engage during each of the three stages of late standardization.

Table 2.3: Stages of Late Standardization and the Corresponding Activities and Capabilities at the Firm Level

	Technological Capabilities & Activities		Standards Capabilities & Activities			
Stages	General Characteristics	Major Activities	General Characteristics	Standards Activities	Standards Capabilities	Organizational Structure
1. Catch-up	Operation	Implement technological solutions provided by others	Passive standards adopters	Some internal standards activities related to quality control and management No external standardization activities	Acquire mature standards and assimilate into production processes and products	Ad hoc quality-control engineers
	Diagnosis	Recognize technological problems and opportunity		Some domestic events and forums related to standards adoption	Minor adaptation of standards according to market needs	Quality standards personnel
	Search and selection	Search and select appropriate technologies				
	Adaptation	Adapt the technologies to local conditions and make minor improvements	Active standards adopters	Participate in domestic standardization	Ample knowledge of standards, including international standards	Quality standards related departments
2. Keep-up	Modification	Modify the technologies in response to changing market conditions	Fast followers	Participate in formal international/ regional SDOs	Communications capability: English fluency a must	Technical marketing divisions: engineers participating in standards activities
	Innovation (development capabilities)	Produce new processes and product designs		Contribute to international standardization by submitting technical opinions/reports to technical committees		Personnel from "listening posts" participate in standardization
3. Forge-ahead	Exploration (research)	Explore new technological paradigms	Developers ("IP firms", w/o manufacturing capabilities)	Lead standardization efforts both in formal international SDOs and consortia	Legal capabilities, especially on intellectual property rights	Standards activities as a core part of R&D
			Major Developers (Leaders)	Chairmanship; Convener ship; Secretariats Representatives in Board of Directors of SDOs or Consortia	Negotiation capability to lead technological efforts	Independent divisions devoted to standards

Source: The author.

CATCH-UP: FROM LATECOMERS TO FAST FOLLOWERS

At the beginning of their technological effort during the catch-up stage, latecomers are faced with limited resources and capabilities. Compared to first- and second movers from advanced economies, they have to overcome additional barriers, including limited knowledge about lead-user markets and limited access to specialized inputs.

During the late-standardization process, firms may engage in five broad kinds of standards activities: namely, (1) identifying the needs for standards to solve "matching problems" (Vries 1999); (2) searching, selecting, and acquiring standards appropriate to their needs within or beyond the firm; (3) implementing and assimilating acquired standards into the production process and enforcing the use of standards such that the adopted standards are rigorously adhered to; (4) adjusting the standards according to local conditions or modifying them in response to changing economic conditions, and (5) developing and diffusing new standards.

The main activities for latecomer firms during the catch-up period are generally from the first to the fourth step.[12] The phase of standards adjustment in the late standardization model is similar to the stage of technological improvement in Kim (1980)'s model. However, while technological-improvement efforts lead to changes in the content of imported technologies, standards-adjustment efforts affect only the ways in which standards are implemented within firms, but not the content of the actual standards adopted in the market. As latecomer firms develop more sophisticated technological and standards capabilities, they become more engaged in external standards development.

During the catching-up stage, latecomer firms acquire and adopt existing standards mostly developed by technological and standards leaders. They go through three major phases: namely, (1) acquisition and implementation, (2) diffusion and maintenance, and (3) adjustment and improvement. In the process of standards acquisition, latecomer firms first identify the need for standards, then search for available standards either within or beyond the firm. After implementing the standards, latecomer firms then engage in diffusing the standards and maintaining them within the firm, such that the adopted standards are rigorously followed. Latecomer firms may have to adjust the adopted standards according to their capabilities and constraints. As in anything, some latecomers are more active than others; passive adopters just adopt whatever standards are available and can be easily acquired. Active adopters, on other hand, spend more effort and time in searching and acquiring appropriate standards and may put some effort into adjusting them for their products and/or production processes.

The three steps of standards acquisition, maintenance, and adjustment may appear similar to the staged models of technological catch-up proposed by Kim (1980) and Lee et al. (1988). However, as in the proposed model of late standardization, technological improvement in the catch-up process eventually reaches the technological limits imposed by the existing standards (catch-up limit in Figure 2.2C). Latecomers may develop technologically by acquiring, assimilating, and improving foreign technologies, and their technological capability may increase. But the extent of their technological development is still within the limits of standards capability. In other words, *technological development is limited by the extent of the standards.*[13] As forerunners continue to push the limits of technological frontiers, they keep generating new standards to sustain their leadership. However much latecomers improve their technological capabilities, the extent of development is always within the limits imposed by whatever standards they adopt. Accordingly, without increasing their standards capabilities and engaging in standardization activities, latecomers can never move beyond catch-up.

During the catch-up stage, latecomers focus their efforts on internal standards activities, rather than external ones. Quality control and management standards are the main focus of latecomers' standards activities during this stage. In fact, as we show later in Chapter Four, quality control and management standards are the main mechanism that enables latecomers to move from the catch-up stage to the keep-up stage. This is because latecomers' competitive advantage relies greatly not only on low-cost factor inputs, but on quality and reliability of products. Good-quality products and reliable delivery would allow latecomers to become part of global supply chains, in which firms from advanced economies dominate. Similarly, during the catch-up stage, governments may also use quality standards as a means to improve and maintain the quality of the products that they export to the world market.

Although in reality firms are situated along the wide spectrum of capability levels, it is necessary for analytical purposes to categorize them according to the firms' standards capability. Among latecomer firms in the catch-up stage, some could be categorized as passive adopters of standards. The specifications, practices, and products that these firms adopt as standards are not from internal development efforts, but mostly imitated from external sources (Refer to Figure 4.2: sources of standards). The factor that distinguishes latecomer firms in this group from one another is their operational capability, i.e., the ability to implement and comply with the acquired standards effectively and efficiently. Firms with greater operational capability generally show better performance than those with less particularly in terms of standards implementation and assimilation.

KEEP-UP: FROM FAST FOLLOWERS TO TECHNOLOGY LEADERS

The second stage of the late standardization process is that of keep-up. Latecomers that have achieved this stage of technological catch-up are, by definition, no longer "latecomers." By now, they are fast followers, or second movers, and have overcome some of the barriers that latecomers normally face.

Broadly speaking, fast followers undertake standards activities that are similar to those in the catch-up stage. They search and acquire existing standards from external sources. Then, they implement and assimilate the standards into their products and processes. As their standards capability improves, they adjust and modify the standards to better fit their unique technical and business conditions. In addition, fast followers start to engage in more sophisticated standards activities, including external standards activities that involve participation in standardization forums.

First and foremost, the main difference between latecomers and fast followers lies in the standards-acquisition process. While latecomers in the catch-up stage are less active about standards acquisition, fast followers participate directly in standards development activities at the international level. By directly participating in technological-standardization activities, latecomers move beyond the first stage to the second stage of late standardization. Participation in international standardization is thus the *event* that triggers a *stage transition*, which is a condition required for an evolutionary model. Even though fast followers' standards capabilities are not strong enough to influence the directions and outcome of the standardization efforts, they can keep up with technological changes by learning about standards and the associated technologies before latecomers that are outside the standardization clubs. By participating in standards forums, fast followers acquire knowledge not only about new technologies but also other important information, such as access-to-market and legislative and regulatory development that may affect technological trajectories in their industries.[14]

We will discuss this important learning effect of standards in detail in the following chapter. For the time being, suffice it to say that fast followers in the keep-up stage could reap second-mover advantages and the resulting above-normal profits when the forerunners start the production of relatively mature products overseas.[15] But the ability to reap the rapidly declining profit margins depends greatly on two important sets of skills and capabilities (Amsden and Chu 2003). One is project and production capabilities that allow them to deliver the products quickly to the market at the lowest cost. The other is the ability to acquire technological knowledge about new products even before they mature, so that once the products reach maturity they can be commercially produced quickly. While latecomers may tap into advanced technological knowledge through various means, such as technical communities (Saxenian and Hsu 2001) and overseas research labs and "listening posts" (Amsden and Chu 2003), standardization forums and communities may indeed be one of the most important. The participation in standardization efforts is thus an important factor that enables latecomer firms to become second movers in high-tech industries that are approaching their mature stages. In the model of late standardization, this is the main criterion that distinguishes latecomers in the catch-up stage from fast followers in the keep-up stage.

In the Abernathy- Utterback model, the change from the Fluid Phase to the Transitional Phase is characterized by the emergence of a dominant design, which propels further standardization of related components and products (Figure 2.2). While standardization efforts may start before the dominant design emerges, the standardization of other technical features of the dominant design may continue for quite some time. By participating in standardization efforts *even* in the later stages of the technology life cycles, fast followers are still able to acquire new technical knowledge, which helps to increase their standards and technological capabilities beyond the catch-up stage.

FORGE-AHEAD: FROM TECHNOLOGY LEADERS TO STANDARDS LEADERS

Late standardizers move from being fast followers to first movers when they are technological leaders. But being technological leaders does not guarantee their status as standards leaders. Late standardizers enter the forge-ahead stage of late standardization and technological catch-up when the standards that they develop or co-develop are adopted by other firms. The main strategic concern that late standardizers have in this stage involves strategic standardization management that regards standards activities as part of the core corporate strategy.

Similar to latecomer firms in other stages, late standardizers in the forge-ahead stage are also engaged in three broad types of standards activities: that is, standards acquisition, maintenance, and adjustment. Yet, the modes and sources for standards acquisition are likely to be different. What makes late standardizers at this stage different from those in earlier stages is their focus on standards development, both internally and externally. Participation in standards development at the technological frontier becomes the main activity for its overall standards efforts. In fact, standards become a core strategic issue for late standardizers in this stage. Once late standardizers have reached the forge-ahead stage of late standardization, they are already technology and standards leaders. Not only do these firms actively participate in standards development, but they also strive to influence the directions and outcome of standardization efforts. They may also co-found standards consortia with existing standards leaders in new technological fields to capture the leadership positions.[16]

CONCLUDING REMARKS

Our model of late standardization and technological catch-up consists of three stages: catch-up, keep-up, and forge-ahead. Catch-up refers to the stage in which latecomers attempt to become second movers or fast followers in terms of technological and standards development. Keep-up is the stage in which fast followers engage in various technological and standards activities to keep up the technological change brought about by the technological and standards leaders. Forge-ahead is the stage in which first movers sustain their competitive advantage not only through technological leadership but also standards leadership. In the following chapters, we will show empirical evidence on different aspects of late standardization to support the proposed model of late standardization, including participation in external standardization activities, adjustment of organizational structure for standards activities, and the roles of the state in late standardization.

CHAPTER THREE

THE ASCENT OF LATE STANDARDIZERS

CONTINUOUS DOMINANCE OF FORERUNNERS ■ EMERGENCE OF LATE STANDARDIZERS ■ LATE STANDARDIZERS AS STANDARDS LEADERS ■ LATE STANDARDIZERS IN SEMICONDUCTOR ■ LATE STANDARDIZERS IN MOBILE TELECOM ■ CONCLUDING REMARKS

A small, yet increasing, number of latecomers have emerged as standards leaders at the global level. This is a significant phenomenon, considering that these latecomers were just manufacturers of low-technology products not very long ago. Their active participation in international standardization is an important indicator of their improvement in efforts and capabilities in late standardization and technological catch-up. As latecomers develop their technological capabilities, they become more involved in international standardization activities, especially in "informal" standards consortia and alliances. Through participation in standards forums, latecomers create the leverage for their technological upgrading and market penetration in the world market. Some latecomers are active and fast followers, who learn about emerging technologies through standardization activities. Others provide technical input that becomes part of new standards. A few of them have even become standards leaders, as they influence the direction of standardization to reflect their strategic interests.

In this chapter, we discuss latecomers' recent emergence in the international standardization arena. Our discussion first focuses on the general pattern of participation of latecomer firms in formal standards development organizations (SDOs). Then, we turn our attention to the participation in standards consortia, where an increasing number of standards for new technologies are developed. Our focus then shifts to the emergence of late standardizers in the semiconductor and telecommunications industries respectively. The discussion in this chapter lays the groundwork for the following chapter where we use the case studies of leading Korean firms to illustrate how latecomers' engagement in international standardization serves as a mechanism for them to move beyond catch-up to become technological and standards leaders at the world technological frontier.

CONTINUOUS DOMINANCE OF FORERUNNERS

As with the case of technological capabilities, standards capabilities vary across firms and countries. A general observation is that firms and governments from industrialized countries have more sophisticated standards capabilities than those from developing economies. As shown in Table 3.1, developed economies have produced far more standards than latecomer countries. The United States alone has almost 100,000 standards in stock, as of 1997. The number is likely to be much greater in recent years, due to the increasing need for compatibility and interoperability standards in the ICT industry. Former socialist countries, such as Russia and China, also have a large number of standards. This is not surprising, considering that standards were used as part of the tools of the state to direct the centrally planned economy (Krislov 1997). Not only do industrialized countries have more standards in stock, they also have standards facilities, institutions, and resources that constitute more sophisticated national standards systems than those of developing countries.

Firms and governments from industrialized countries are active in standards activities not only at the domestic level, but also at the international level. They produce the majority of the world's de jure standards as well as de facto standards, primarily due to their technological leadership. Although there is no information available on the number of de facto international standards, it is probably valid to assume that developed economies produce most of the world's de facto standards, at least those that are used in international transactions. Developing-country firms and governments have limited involvement in developing standards at the international level and mostly adopt standards developed elsewhere.

Table 3.1: National Standards in Select Industrialized and Latecomer Countries

Industrialized Country [Foundation year, private (P) or Government (G)]	Number of Public Standards	GDP (Billions USD)	Annual Budget (Million USD)	Latecomer Country [Foundation year, private (P) or Government (G)]	Number of Public Standards	GDP (Billions USD)	Annual Budget (Million USD)
U.S.A. (1918 P)	93,000	11668	30.0	China (1957 G)	17,000	1649	2.3
Germany (1917 P)	37,000	2714	110.0	India (1987 G)	16,000	692	n.a.
Russia (1991 G)	22,000	582	5.5	Taiwan (n.a.)	13,000	305	n.a.
France (1926 P)	19,500	2003	80.0	Turkey (1954 G)	12,600	302	41.3
Japan (1949 G)	18,000	4623	14.6	S. Korea (1961 G)	9,400	680	2.3
Italy (1921 P)	15,000	1672	14.5	Brazil (1940 P)	8,000	605	7.5
U.K. (1901 P)	13,700	2141	225	Argentina (1935 P)	7,900	152	4.0
Sweden (1922 P)	12,100	346	37.0	Mexico (1943 G)	6,028	676	0.3
Spain (1985 P)	11,900	991	25.0	Colombia (1963 P)	4,000	97	4.5
Belgium (1946 P)	8,545	350	0.5	Indonesia (1984 G)	3,600	258	0.4
Finland (1924 P)	7,670	187	13.7	Venezuela (1973 P)	3,241	109	4.0
Austria (1920 P)	7,500	290	19.5	Philippines (1964 G)	3,200	86	0.9
Netherlands (1916 P)	6,000	577	31.0	Malaysia (n.a., P)	2,000	118	n.a.
Canada (1970 G)	5,500	980	11.2	Thailand (1968G)	1,500	163	15.3
Australia (1935 P)	5,400	631	10.7	Singapore (1963 G)	713	107	2.3

Source: Adapted from National Institute of Standards and Technology (1997)

Notes: i) n.a.= data not available. GDP: Gross Domestic Product.

ii) Budget figures are for the main national standards organizations, e.g., the U.S. budget figure is for ANSI only.

iii) Correlation coefficient between the number of public standards and GDP (R^2) is 0.93.

However, as trade between developed and developing countries grows, standards become even more important for developing countries. Many of the emerging markets have become the battleground of competing standards from developed countries. In the mobile communications industry, for instance, leading firms from developed economies compete against each other, such that their preferred standards are adopted by firms and governments in developing countries (Funk 1998).

Without advanced technologies and innovations, developing-country firms have no capability and power to determine de facto standards at the international level. At the national level, local firms that monopolize domestic markets may have been the sources of domestic de facto standards of sorts. However, with the growing trade liberalization in recent years, local firms have to compete directly with multinational corporations even in the domestic markets. They may not command enough market shares to push for their standards. Particularly in the markets with new products and/or technologies, multinational firms tend to become the sources of de facto standards. As we show later in our case studies of Thai firms in the semiconductor and telecommunications industries, latecomer firms just adopt standards already available in the developed markets.

This is also true for de jure standards at the international level. Firms and governments in developing countries increasingly adopt international standards or standards developed by standardization bodies in advanced economies. As shown in Table 3.1, as great as 90 percent of Indonesia's standards are adopted from international standards. The figure is also high for Turkey, where 85 percent of domestic standards are international in origin. Similarly, according to our interviews with officials at the Thai Industrial Standards Institute, most of the new industrial standards adopted in the country are translated or adapted from international standards, such as ISO and IEC standards.

As a matter of course, latecomers do not have any influence on standard-setting processes in developed economies. National standard-setting is usually an internal affair. Foreign firms and organizations are sometimes allowed to become members of other countries' domestic standards organizations. But their influence on the outcome is likely to be negligible, unless their presence is very large in the country.

Developing countries also have limited involvement in standards development at the regional and global levels. They may be members of various international standardization bodies, such as the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunication Union (ITU). They may also be members of regional bodies, such as the Pacific Area Standards Congress (PASC) or Pan American Standards Commission (COPANT). But their involvement has not been very active.

For instance, in the case of the ISO, developing countries do not actively participate in the technical committees and working groups, where standards are proposed, drafted, negotiated and formulated, or in the elaboration of internationally agreed standards. The numbers of secretariats in the technical committees and subcommittees from developed countries far exceeds those of developing countries. The top three countries, namely, the United States, Germany, and the United Kingdom, account for more than half of the total secretariats. This is also true at the level of working groups, in which the three countries hold almost 60 percent of the total convenerships. As secretariats and conveners are responsible for leading the work on standards development, the number of secretariats and conveners indicates the level of participation in the ISO. It is clear that developing countries have very limited roles in international standards development (Table 3.2).

Table 3.2: ISO Members' Participation in Standards Development Process, 2002

Rank	Member country	Number of Secretariats (TC/SC)	Number of Convener-ships (WG)	Total	Rank	Member Country	Number of Secretariats (TC/SC)	Number of Convener-ships (WG)	Total
1	U.S.A.	138	494	632	22	Portugal	3	8	11
2	Germany	121	349	470	23	South Korea	5	5	10
3	U.K.	104	345	449	24	Brazil	4	5	9
4	France	84	188	272	25	Poland	5	3	8
5	Japan	39	113	152	26	Malaysia	3	4	7
6	Sweden	27	103	130	27	Ireland	-	6	6
7	Netherlands	19	73	92	28	Iran	3	2	5
8	Canada	20	66	86	29	Israel	3	2	5
9	Australia	15	56	71	30	New Zealand	2	2	4
10	Norway	18	35	53	31	Czech Republic	1	2	3
11	Italy	14	38	52	32	Greece	1	2	3
12	Switzerland	19	31	50	33	Turkey	3	-	3
13	Denmark	7	32	39	34	Colombia	1	1	2
14	Belgium	4	26	30	35	Hungary	2	-	2
15	Russia	15	11	26	36	Singapore	-	2	2
16	China	6	13	19	37	Thailand	-	2	2
17	Spain	9	8	17	38	Romania	1	-	1
18	Finland	3	12	15	39	Ukraine	-	1	1
19	Austria	3	9	12	40	Slovakia	1	-	1
20	South Africa	10	2	12	41	Uruguay	-	1	1
21	India	8	3	11		Total	721	2055	2776

Source: Adapted from ISO Annual Report 2002

Note: TC – Technical committees, SC – Sub-committees, WG – Working groups.

EMERGENCE OF LATE STANDARDIZERS

Despite the continuous dominance of developed-country firms and governments, a small, yet increasing, number of latecomers have recently emerged as important players in the international standardization arena. Some of these firms have also shown leadership in standardization processes, as their technologies are adopted as part of standards used by other firms, even the forerunners from advanced economies.

Due to the increasing complexity and systems characteristics of information and communication technologies, successful de facto standardization by a single firm is rare. For instance, complexity increases for at least an order of magnitude for each new generation of communications standards (Woodward 2005). As a result, the cost of standards development has increased in most cases beyond the level that an individual firm would be able to bear, even for large corporations from advanced economies. The growing size and complexity of standards also increases the demand for the specialized skills required in standards development. In addition, because of economic globalization, international markets are now a target of most standards. Involving companies from different countries and regions may also increase regulatory and market acceptance for new standards and products.

As de facto standardization is extremely difficult for advanced firms, it is thus almost impossible for latecomer firms to establish de facto standards for the world markets. De jure standardization becomes the main, if not only, process in which late standardizers expend their efforts and resources on participating.

Late standardizers participate in standardization activities in all types of standardization forums, ranging from formal standards development organizations (SDOs) and "informal" standards consortia and alliances. Broadly speaking, there are four groups of forums in which latecomers participate: domestic SDOs, domestic consortiums, international SDOs, and international consortiums. Late standardizers do not limit their geographical reach either, participating in domestic, foreign, regional, and global forums. In this section, we pay particular attention to their participation in international SDOs and consortia. Each of them has distinctive relationships with the three stages in our proposed model of late standardization and technological catch-up

LATECOMERS IN INTERNATIONAL SDOs

Latecomer firms and governments participate in various types of formal standards development organizations. Some SDOs, such as the ISO and the IEC, are non-governmental organizations, although their standards often become law through treaties or national standards. Other SDOs are established by international treaties, such as the ITU and the Codex Alimentarius Commission, which promotes international standardization for food safety. Different standards organizations have different rules and regulations regarding membership. In some organizations, only one national entity can represent each country as a voting member. In others, there could be several representatives for each country, from either the private or public sectors. Most countries participate in international SDOs that adopt the one-country-one-representative membership system, such as the ISO and the IEC

Although firms and governments from advanced countries retain their influence on international standardization, there is increasing evidence supporting the emergence of successful late standardizers. One indicator is late standardizers' increasing participation in technological standardization at the international level. In recent years, an increasing number of latecomers have significantly increased their presence in standards development efforts in both formal and informal forums at the international level.

Meanwhile, there is an increasing gap among developing countries in terms of standards capabilities and participation in standards development. A small number of latecomer firms are entering the forge-ahead stage in our model of late standardization. Others are either in the keep-up stage or still further behind in the catch-up stage.

With a quick glance at the membership structures of international SDOs, the participation of latecomers in formal standardization forums may not appear to have increased. This is because most key international standardization organizations, such as the ISO and the IEC, still restrict the membership to only one member per country. This rule is important, especially when a draft standard is being voted on for approval. While the voting process is important in determining whether a draft will be approved as a standard, the actual standardization activities occur at the lower levels, that is, at the levels of technical and/or working committees and subcommittees. It is at this level that the increasing participation of latecomer firms is more noticeable.

As an illustration, let us look at the cases of South Korea. In a formal international SDO, a member country normally designates one standards organization to represent the country. This "member body" could be a government agency or a private non-profit organization. In case of South Korea, the Korean Agency for Technology and Standards (KATS) under the Ministry of Commerce, Industry and Energy (MOCIE), represents as the national member body in the ISO and the IEC. On the other hand, the Ministry of Information and Communication (MIC) represents South Korea in the ITU. These governmental organizations have represented South Korea in both international SDOs from the beginning of the country's membership and remain to be the sole representatives. However, the seemingly constant membership level belies the increasing participation and contribution of other Korean institutions and firms in the ISO, the IEC, and the ITU.

As mentioned earlier, it is at the level of technical committees/subcommittees (TC/SC) or working groups (WG) where the detailed standards are actually proposed and drafted. To participate in standardization activities of the technologies of interest, the member body that represents the country normally designates a local secretariat institute/organization for each of the technical or working committees that the country wants to participate. The secretariat institution could be a research institute or a semi-public organization. These secretariat organizations then set up domestic working groups that correspond to the TC/WG at the international level. The domestic working groups generally comprise representatives from research institutes, government agencies, private firms, and sometimes individual experts.

Individuals or firms may present their standard drafts at international standards organizations through the secretariat organizations, which review and then approve the proposals. Representatives from private firms can also join international standardization activities at the TC/WG levels as the representatives of the countries. The level of a country's contribution to standardization processes can be judged, to some extent, by its contribution and leadership as the secretariats of technical committees/subcommittees and/or as the conveners of the working groups for each committee.

As shown in Table 3.3, South Korea and China are the most notable among latecomers, in terms of participation in ISO standardization activities. South Korea, in particular, has made significant progress in recent years in leading and contributing to the international standardization efforts in the ISO. While the numbers are still very small compared to developed economies, it is evident that South Korea has substantially increased its efforts in the past decade. There was only one Korean representative as the Convener of an ISO Working Group in 1998. By 2004, there were as many as 21 of them participating as the Conveners of working groups or the secretariats of technical committees/subcommittees.

On the other hand, the number of ISO secretariats and convenerships held by other latecomers has not changed as much. China and India are two of the most active participants among latecomer/developing countries. Yet, their leadership and contribution in 2004 remain almost at the same level as in the late 1990s. One possible explanation is that the types of standards and technologies to which latecomers channel their efforts and resources are not covered by the ISO.

Table 3.3: Level of Contribution and Leadership of Latecomers in ISO Standardization, 1998-2004

	Year	1998		2000		2002		2004	
	Types of leadership	Secretariat TC/SC	Convener WG	Secretariat TC/SC	Convener WG	Secretariat TC/SC	Convener WG	Secretariat TC/SC	Convener WG
Asian Latecomers	S. Korea	0	1	0	2	5	5	9	12
	China	6	15	6	13	6	13	9	16
	India	11	5	8	4	8	3	8	5
	Malaysia	2	2	2	2	3	4	4	4
	Singapore	0	2	0	3	0	2	0	2
	Thailand	0	1	0	1	0	2	0	1
Other Latecomers	Brazil	4	2	4	5	4	5	2	6
	Colombia	1	0	1	1	1	1	1	3
	Mexico	0	0	0	0	0	0	0	1
	Turkey	4	0	3	0	3	0	3	0

Sources: Adapted from ISO Annual Reports, various years

Note: TC/SC = technical committee/subcommittees, WG = Working groups

The telecommunications industry is one of a few industries, in which latecomers have particularly concentrated their efforts in recent years. We can thus expect their active participation in telecommunications standards forums. In the ITU, for instance, the participation of some latecomer firms and governments has been noticeable in recent years. In addition to the participation as designated institutions by member states, a number of latecomer firms have joined the ITU as sector members. Generally, major domestic telecommunications service providers in developing countries participate in the ITU as sector members. These service providers are often state-owned enterprises. What distinguishes successful latecomer countries from others is that, even domestic firms that are not service providers, such as equipment manufacturers, participate in the standardization processes of the ITU. As with the case of forerunner firms from developed economies, these latecomer firms participate actively in the ITU so as to influence the standardization outcome at the level of Study Groups. It is at this level where the actual standards are discussed, drafted and contested by technical experts.

As shown in Table 3.4, South Korea is again the most active latecomer country, in terms of its participation in the ITU. The country has 16 members in the ITU, 9 of which are sector members. India and China are second and third, with totally 13 and 9 members. Although these figures are less than one-tenth of that of the United States, their presence at the ITU is more noticeable than before.

Table 3.4: Participation of Latecomers in ITU, 2004

Country	Membership Size	# of Sector Members	Examples of Sector Members
South Korea	16	9	Samsung Electronics; LG Electronics; LG Telecom; KT Corporation; SK Telecom; ETRI; DACOM; NIDA; KADO
India	13	9	BSNL; COAI; Data Access; MTNL; Reliance Infocomm; Sasken Communication Technologies; TDSAT; TRAI; TCIL
China	8	7	Huawei Technologies; ZTE, China Unicom; China Telecom; China Netcom; Alcatel Shanghai Bell
Malaysia	8	6	Cape Range Wireless; Celcom (Malaysia); Digi Telecom; Maxis Communications; Telekom Malaysia; TIME dotCom
Singapore	5	2	Starhub; Singtell
Thailand	4	2	TAC; AIS
Brazil	6	3	Embratel; D&D International; Telemar Norte Leste
Mexico	7	4	TELECOMM; SATMEX; TELMEX
Cf.			
United States	162	117	3Com; Microsoft; AT&T
Japan	58	46	NTT; NEC; Canon
United Kingdom	41	31	Vodafone; British Telecom

Source: Adapted from ITU membership report on website, www.itu.org

Notes: (1) ITU membership includes ITU-R (Radio standardization), ITU-T (Telecom standardization), and ITU-D (Telecom development) (2) There are three types of membership: member states, sector members, and associates. Sector members include private firms and scientific or industrial organizations approved by the Member State

STANDARDS CONSORTIA AND ALLIANCES

The increase in participation of latecomers in international standardization is more noticeable in standards consortia and alliances in fast-changing fields of technologies. In fact, standardization activities of new technologies are now occurring more outside than inside formal SDOs. One reason for this is speed. Standardization processes in formal SDOs usually take many years before standards are finally approved. For instance, some ISO standards make it from start to finish within four years or less, but many standards take as many as nine years (Eicher 1999). The average development time for ISO standards improved from 92.1 months in 1988 to between five to six years in 1997 [Hesser (1992) and ISO (1998) cited in Vries (1999)]. But it is still a long period of time. By the time of the approval, many technologies and standards, especially in fast-changing fields such as ICT, may already be outdated. Latecomer firms that aspire to be become standards leaders, therefore, cannot be content with the situation. An increasing number of latecomer firms have already participated directly in international standardization consortia and alliances, in which candidate technologies are more fluid yet closer to the world technological frontier.

As Cargill (2001) argues, informal consortia and alliances are more suitable to developing standards in rapidly-changing fields of technologies than formal SDOs for two main reasons: their commitment and the ability to implement the standards outcome. First, technical task forces and working groups in consortia are more likely to proceed according their mandated schedules. Because consortia participants have a vested interest in producing standards, their level of commitment to the successful development of standards is greater than those participating in formal SDOs. The second advantage of consortia is their ability to set up and run tests for implementations of their specifications. Because of the contractual arrangement with participants, many consortia are able to compel their members to adopt and implement their standards and specifications in preference to other standards. This means consortium standards are more likely and quickly adopted by the market than SDO standards. Therefore, latecomer firms that join these standards consortia are likely to have more knowledge about what standards are to be adopted in the marketplace than those who do not join.

The advantages of participating in standards consortia and alliances are not limited to the knowledge about the technologies used in standards and the information regarding market access. Latecomers can also gain the knowledge as to which technologies are likely to be adopted by other firms and eventually by the future market. This knowledge is critical for latecomers, especially during the time when even technological leaders have to form alliances to stay competitive. We will discuss this issue later in Chapter Four where we examine the learning benefits that latecomers gain from participating in standardization efforts.

Consortia-based standards development is not without problems. By its very nature, standards development in consortia, especially for communications standards, requires an agile approach; every time a standard consortium adopts a change, models must be updated and re-run. More consortium members may also mean more changes required, which in turn affect the speed and costs of development.

STANDARDS FORUMS IN OTHER COUNTRIES/REGIONS

Late standardizers have also become more active in participating in standardization activities in countries and regions outside their own. This phenomenon is significant because it indicates latecomers' efforts to overcome two main disadvantages of being a latecomer: that is, being distant from the lead-user markets and being distant from the sources of specialized knowledge. By participating in standardization activities in developed markets and regions, latecomers acquire the opportunities to overcome the latecomer disadvantages.

One example is the participation of Samsung Electronics of Korea in SELETE (Semiconductor Leading Edge Technologies), a Japanese R&D consortium established and managed jointly by 10 Japanese semiconductor manufacturers. While Samsung participates in the group only as a non-voting member, the participation indicates its efforts to be part of a R&D consortium to acquire advanced manufacturing technologies, which could become de facto standards of the industry. As early as 1997, SELETE made a contract with Samsung for the evaluation program of semiconductor manufacturing equipment and materials for 300mm wafers. The purpose of the evaluation program aimed to encourage the 300mm wafer manufacturing as well as to reduce the R&D cost, since the technology of manufacturing equipment and materials is pre-competitive for semiconductor manufacturers today. As the leader in DRAM manufacturing, Samsung was important for the Japanese consortium, not only as a future client but also the "tester" of new technologies and standards.

Late standardizers have become more active in participating in standardization activities even in the regions outside their own. One good example is latecomers' participation in the European Telecommunications Standards Institute (ETSI), the official standardization organization for information and communication technologies in Europe. While full membership of ETSI is limited to only firms and institutions from countries within the European Postal and Telecommunications Administrations (CEPT) area, latecomer firms and research institutes from Asia and other regions can participate in ETSI as associate members in the standardization meetings. China and Taiwan are particularly active in ETSI, having more associate members than other latecomer countries. South Korea is less active in ETSI, having only the Electronics and Telecommunications Research Institute (ETRI) as an associate member (Table 3.5).

The reason that South Korea has limited representation in ETSI may be attributed to Korean firms' market-access strategies for new products and services. According to our interviews with Korean executives and government officials, Korean firms naturally focus first on the domestic market, where they can test new products and services. Once they have improved their capabilities in terms of technology and other complementary assets, such as marketing and distribution channels, they move onto the export markets. The first overseas market that they focus on is the U.S. market, which is the largest market for many Korean latecomers.[17] The European market tends to come after that. To many Korean firms, the Japanese market appears the most formidable. Such step-by-step market-access strategy may partially explain why there is limited representation of Korean firms in European standardization forums. They first focus their efforts and resources on standardization activities in the United States before other countries and regions. A Korean government official indicates further that many Korean firms consider the United States to be more technologically advanced and active than in Europe.

Table 3.5: Participation of Latecomers in ETSI, 2004

Country	Number of members	Examples of associate members
China	7	Huawei, HYT, RITT, ZTE, Wuhan Tianyu, Shenzhen Mingwah Aohan, Sandmartin Electronic
Taiwan	7	ASUSTeK, CCL/ITRI, CGC, Chi Mei Communication, CHTTL, GoldKey Technology, Quanta Computer
India	4	Flextronics, HCL Technologies, Saske Communication, Tata Consultancy
Singapore	2	I'M Technologies, Institute for Infocomm Research
South Korea	1	ETRI
Malaysia	1	CMC
Thailand	0	-
Brazil	0	-
Cf.		
United States	46	Apple, Motorola Broadband, Oracle
Japan	1	NTT

Source: ETSI website: www.etsi.org

LATE STANDARDIZERS AS STANDARDS LEADERS

Although still limited in number, some latecomer firms have moved beyond being standards followers to become standards leaders at the world technological frontier. In the semiconductor and mobile telecommunication industries, for instance, a few late standardizers have moved successfully into the forge-ahead stage in our model of late standardization and technological catch-up. One indication of being a standards leader is that their proprietary technologies are included in international standards that are adopted by other firms. Table 3.6 highlights some examples of late standardizers from South Korea that have become not only market and technology leaders, but also standard leaders in the semiconductor and mobile telecommunications industries.

Table 3.6: Examples of Korean Standards Leaders in Semiconductor and Mobile Telecom

Sector	Examples	Leading Firms
Semiconductors	DDRII, DDRIII	Samsung, Hynix
Mobile Telecommunications	WiBro	Samsung, LG
	Terrestrial digital multimedia broadcasting	MBC, Samsung Electronics, KBS, LG Electronics

In the following section, we discuss the case studies of successful Korean late standardizers in the semiconductor and telecommunications industries. We examine how these Korean late standardizers manage to transform themselves from being latecomers into fast followers, then into technology leaders, and finally into standards leaders.

LATE STANDARDIZERS IN SEMICONDUCTOR

Standards have become more and more important in all segments of the semiconductor industry. One indication of the increased importance is the number of standards required for newer generations of semiconductor products (Table 3.7). For instance, in the early 1990s, there were only about 10 technology standards for command and package for DRAMs and other memories operated at a speed of 33MHz. However, as the speed of memories increased to 100MHz by the late 1990s, the number of technology standards jumped substantially. The second generation DDR DRAM (DDR2) alone has about 330 standards (Shin and Jang 2005).

Table 3.7: Technological Standards for DDR2

	Major Items	Number of Standards
Function	Circuit, Addressing, Logic, Read/Write, etc.	About 100
Specification	Power, Test, Temperature, etc.	About 200
Package	Pin-out etc.	About 10
Module	UDIMM, RDIMM, SODIMM etc.	About 20

Source: Shin and Jang (2005)

Similar to the telecommunications industry, it is now believed that no single company in the semiconductor industry today—not even a large company, such as IBM or Intel—has enough power to automatically drive de facto industry standards. Companies are thus cooperating in standardization and R&D efforts now that OEMs and integrated circuit (IC) design houses are outsourcing more and more of their manufacturing, assembly and development.

While semiconductor manufacturers all desire to have their own competitive edges, the buyers want standardization. From the buyers' perspectives, standardization leads to low prices and broad supply. Uniformity in terms of technical terms and definitions contribute significantly to the consistent quality and reliability of products. Standardization also means interchangeable multiple supplier solutions. From the manufacturers' perspective, standards create large demand and pre-sold customer base.

The increasing number of standards includes not only the specifications for semiconductors themselves, but also the technical requirements for manufacturing processes. This means equipment manufacturers also need to be involved in standardization activities. For instance, semiconductor manufactures try to utilize their manufacturing capacity more efficiently by introducing more automated manufacturing systems. As the industry is preparing itself for e-Manufacturing and e-Diagnostics, more standards are being developed to accommodate the new manufacturing technologies. Because de facto standardization is extremely difficult, if not possible, standards organizations become critical in providing forums for firms in the semiconductor industry to jointly develop de jure standards.

SEMICONDUCTOR STANDARDS ORGANIZATIONS

There are a number of standardization organizations in the semiconductor industry, covering various aspects of the products as well as fabrication and packaging processes. Compared to other sectors with more rapidly changing technologies, such as mobile telecommunications, the number of standards organizations for semiconductors is relatively stable and consolidated. This is because, after four decades of technological development, the industry is maturing and approaching the Specific Phase of the Abernathy-Utterback Model.

Semiconductor SDOs vary significantly, in terms of membership size, areas of standardization, and influence on the market (Table 3.8). For instance, the Semiconductor Equipment and Materials International (SEMI) has a membership of more than 2200 firms, making it the largest industry group for the semiconductor industry. SEMI standards cover every aspect of semiconductor manufacturing: equipment automation (hardware and software), facilities, gases, materials, microlithography, packaging, process chemicals, and traceability. Another important standards organization for the industry is the Joint Electron Device Engineering Council -Solid State Technology Association (JEDEC), with a membership of about 300 firms. While both SEMI and JEDEC deal with a wide range of standards, often overlapping with one another, each organization has its main focus. While SEMI is strong for its "front end processing" standards, JEDEC is known for its "back-end processing" standards. Major semiconductor manufacturers therefore participate in both organizations.

The Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) is another globally recognized standards-setting body that covers, but is not limited to, the semiconductor industry. IEEE-SA develops consensus standards through an open process. It has a portfolio of more than 870 completed standards and more than 400 standards in development. Its focus on nanotechnology standards is part of a greater effort by the IEEE Nanotechnology Council, a multidisciplinary group formed to advance nanotechnology. Meanwhile, there are also a few other smaller standards organizations dealing with software for semiconductor fabrication processes, such as Accellera and the Open SystemC Initiative (OCSI).

Table 3.8: Examples of Standards Development Organizations in the Semiconductor Industry

Examples of SDOs	Main Areas of Standardization	Membership Size	Examples of Leading Members (Latecomers in bold)
SEMI: Semiconductor Equipment and Materials International	Wide range, but focus on "back-end"* standards for packaging,	2,230	All major semiconductor firms
JEDEC: Joint Electron Device Engineering Council -Solid State Technology Association	Wide range, but focus on "front-end"* standards for fabrication of chips and components, especially memory	270	Intel; **Samsung**; Micron Technology; Microsemi; Texas Instruments; Amkor; **Hynix**
ISQED: International Symposium on Quality Electronic Design	Silicon manufacturing, circuit design, and electronic design automation (EDA)	269	AMD; Synopsys; Texas Instruments; IBM; Hitachi; **Samsung; TSMC**
OC-PIP: Open Core Protocol International Partnership	Open Core Protocol (OCP)	120	Texas Instruments; STMicroelectronics; Toshiba Semiconductor; Nokia
EDAC: Electronic Design Automation Consortium	Electronic Design Automation	100	Synopsys; Cadence Design Systems; Mentor Graphics
IEEE-SA: Institute of Electrical and Electronics Engineers Standards Association	Wide range of information technology and telecommunications	70 (corporate)	Intel; Infeneon; IBM; Sun; Panasonic; Sanyo; Freescale; Cadence; Synopsis
SIA: Semiconductor Industry of America	International Technology Roadmap for Semiconductors (ITRS)	33 (charter)	Intel; AMD; Rambus; IBM; Micron; Freescale; TI
Accellera	Hardware-description languages (HDL)	26	Intel; IBM; Sun; NEC; Toshiba
OSCI: Open SystemC Initiative	SystemC language (an HDL)	23	ARM; Mentor Graphics; Royal Philips Electronics; STMicroelectronics; Synopsys
APiA: Advanced Packaging and Interconnect Alliance	Advanced packaging and interconnect technologies	15	August Technology; Ultratech; Unaxis; Ebara
SEMATECH	Advanced manufacturing techniques	12	AMD; Freescale; IBM Infineon; Intel; Panasonic; **Samsung; TSMC**

Sources: Websites of the standards development organizations

LATE STANDARDIZERS IN SEMICONDUCTOR CONSORTIA

The participation of latecomers is increasingly noticeable in semiconductor standards consortia. As an example, Table 3.9 shows a recent membership breakdown of SEMI, a major standards consortium for semiconductors. While a large majority of the members are from

North America, Japan, and Europe, latecomer firms from Korea, Taiwan, and Singapore constitute a significant proportion of the overall membership. Members from the three latecomer countries account for 15 percent of the overall SEMI membership.

Table 3.9: SEMI Membership, 2003

Region/Country	Number of Firms	%
North America	1,032	46
Japan	583	26
Europe	263	12
South Korea	135	6
Taiwan	132	6
Singapore	62	3
China	9	0.4
Rest of the World	15	0.6
Total	2,231	100

Source: Adapted from SEMI website: http://wps2a.semi.org

Latecomers are also present in other semiconductor SDOs. Samsung of Korea and TSMC of Taiwan are two members from latecomer countries in the International SEMATECH Manufacturing Initiative (ISMI). ISMI is a global consortium of leading semiconductor manufacturers, including AMD, Freescale, Hewlett-Packard, IBM, Infineon, Intel, Panasonic, Philips, Samsung, Spansion, TSMC, and Texas Instruments. Another important semiconductor SDO is the JEDEC Solid State Technology Association, which is the main forum that we use as our case study in examining late standardizers' participation in standardization activities.

Brief description of JEDEC

The JEDEC Solid State Technology Association or JEDEC in short, is the leading developer of standards for the solid-state industry. JEDEC was founded in 1960 as a joint activity between the Electronic Industries Alliance (EIA), a trade organization for electronics manufacturers and the US-based National Electrical Manufacturers Association (NEMA). JEDEC is now officially the semiconductor engineering standards body of the EIA, which is accredited by American National Standards Institute (ANSI) to help develop standards on electronic components, consumer electronics, electronic information, telecommunications, and Internet security. There are about 270 company members in JEDEC, including some of the world's largest semiconductor and electronics companies.

Almost 2400 participants, appointed by some 270 member companies, work together in 50 JEDEC committees to develop standards and technical guidelines for every segment of the semiconductor industry. As companies have diverse interests and committed resources for standards activities, not all company members participate in JEDEC committees and the number of companies associated with each committee is not the same. These committees, subcommittees, and task groups are the working groups responsible for developing standards documents under formal charters approved by the JEDEC Council. Each committee has a clearly-defined scope of activity in order to avoid overlap of responsibilities among committees and the resulting confusion. The differences in scope require that committees cooperate with one another so as to complete their deliberations. JEDEC is notable for its development of standards for memory products, which are one of the most important segments of the semiconductor industry. JEDEC is accredited by the American National

Standards Institute (ANSI) as the source for the U.S. national standards for the semiconductor industry.

Table 3.10: JEDEC Membership 2005

Region/Country	Number of Firms	%
North America	181	68
USA	175	66
East Asia	65	24
Japan	24	9
Taiwan	23	9
Korea	6	2
China	5	2
Singapore	3	1
Europe	18	7
Rest of the World	3	1
Total	267	100

Source: Adapted from JEDEC website: http://www.jedec.org

As mentioned earlier, there are a significant number of latecomer firms in JEDEC (Table 3.10). As of 2005, there are about 40 latecomer firms from Taiwan, Korea, China, Singapore, Malaysia, and Thailand participating in various activities of the standards organization. Among these latecomer firms, Samsung is arguably the most prominent member, not only an active participant but also as an active leader in standards development activities. Other prominent late standardizers in JEDEC include Hynix (Korea), VIA Technologies (Taiwan), and Hana Electronics (Thailand).

In Chapter Four, we will discuss in detail how late standardizers gain from participating in semiconductor standardization activities. We use the case study of Samsung Electronics' participation in JEDEC as an illustration of how engagement in external standardization activities is an important part of technological catch-up efforts and how a latecomer has managed to move beyond catch-up and keep-up and forge ahead of the forerunners.

LATECOMERS IN MOBILE TELECOM STANDARDIZATION

The telecommunications industry, broadly defined, is another industry in which late standardizers have emerged as important players in recent years. Standardization has always played a critical role in the telecommunications industry. As individual information and communications technologies (ICT) become more advanced, the whole ICT systems themselves become complex and diverse. Their technical and commercial success critically depends on interoperability and compatibility that guarantee the quality and reliability of the information exchanged. Standardization is *the* means to achieve such interoperability and compatibility. Our main focus is on the mobile telecommunication, one of the fastest-growing and largest segments of the telecommunication industry today.

Standardization activities in telecommunications have traditionally occurred in prominent international standards organizations, such as the Geneva-based International Telecommunication Union (ITU). The ITU-Telecommunication Standardization Sector (ITU-T) is one of the three sectors in the ITU and is the main forum for telecommunications standardization among its 189 member states, 650 sector members, and 50 associates.[18]

There are also regional standardization bodies that focus on telecommunications technologies. One important example is the European Telecommunications Standards Institute (ETSI), Based in Sophia Antipolis, France, the ETSI is the main organization for telecommunications standardization within Europe.

Although the ITU and the ETSI are still prominent forums for telecommunications standardization, an increasing number of mobile telecommunication standards have been developed outside the traditional, formal SDOs. An increasing number of consortia and alliances of firms have been formed to facilitate the efforts to increase interoperability and compatibilities among telecommunications products and services. According to a database compiled by Consortiuminfo.org, a website devoted to information on standardization consortia, there are about 70 international consortia and alliances working on various areas of telecommunication standardization. Many of these consortia focus on mobile and wireless communications technologies.

LATECOMERS IN MOBILE TELECOMMUNICATION STANDARDIZATION

A few latecomers have become active in mobile telecommunication standardization in these international consortia. As Table 3.11 shows, latecomers participate in standards development in some of the major consortia in various degrees. It is noticeable that the a few latecomer firms, such as Samsung Electronics and LG Electronics from South Korea, and ZTE and Huawei Technologies from China, are active in many of these consortia. In fact, these well-known latecomer firms participate in these consortia not merely as observers or passive participants, but as active developers of new standards.

Table 3.11: Examples of Standards Development Organizations in the Telecommunications Industry

Examples of SDOs	Areas of Standardization	Membership Size	Examples of Members (Asian Latecomers)
CDG: CDMA Development Group	3G CDMA wireless systems	120	China: Beijing Capitel, China Unicom, Huawei Technologies, Ningbo BIRD, ZTE, Shenzhen Morlab Communications Technology, RITT Korea: Hyundai Syscom, Samsung Electronics, LG Electronics, LG Telecom, SK Telecom, KT Freetel Indonesia: PT Indosat Pdk. India: Tata Teleservices, Reliance Taiwan: APBW
3GPP: Third Generation Partnership Project	Third-generation mobile system based on GSM technologies	6 SDOs 274 firms	7 firms from China and 9 firms from Korea (see Table 3.12)
3GPP2: Third Generation Partnership Project 2	Third-generation mobile system based on CDMA technologies	5 SDOs 80 firms	5 firms from China and 7 firms from Korea (see Table 3.13)
IETF: Internet Engineering Task Force	Internet standards, especially those of TCP/IP protocol suite	No formal membership, but 1400 attendees at the 59th Meeting in Seoul, Korea	Leading Korean firms, e.g., Samsung, LG, KT, SK Telecom, participate in IETF meetings and standards activities
Open Mobile Alliance	Mobile service enabler specifications	26 (sponsors) 96 (full) 290 (associate and support)	Korea: Samsung, SK Telecom (sponsors), KT, LG Electronics, LG Telecom (full members) China: China Mobile Communications, China Telecom, China Unicom, Huawei Technologies, ZTE (full members) Taiwan: BenQ (sponsor)
WiMax Forum	Broadband Wireless	12 (board) 85 (principal) 123 (regular)	Korea: KT, Samsung (board) SK Telecom, LG (principal) China: ZTE (board) Huawei Technologies, Shenzhen Powercom (principal)

Sources: Websites of the standards development organizations

One of the most important and fast-changing areas for standardization in the telecommunications industry is mobile communications. While there are already many standards consortia for mobile communications and the number is increasing, two of the most important standards consortia in mobile communications in recent years are the 3rd Generation Partnership Project (3GPP) and its sister forum, 3GPP2. We discuss these two prominent standards consortia with the focus on the involvement of latecomers.

3GPP and 3GPP2

Arguably, 3GPP and 3GPP2 are currently two of the most important standardization consortia for mobile communications. When the discussions on the Third Generation standards for wireless communication started in 1998 under the ITU's International Mobile Telecommunications (IMT-2000) initiative, it became evident that traditional standards-setting processes were too slow given the speed of technological change. The concept of a "Partnership Project" was pioneered by the European Telecommunications Standards Institute (ETSI) with the proposal to create a Third Generation Partnership Project (3GPP) focusing on Global System for Mobile (GSM) technology. The main objective of 3GPP is to produce globally applicable standards and technical specifications for a 3rd Generation Mobile System based on evolved Global System for Mobile Communications (GSM) core networks and the related radio access technologies. At the same time, a parallel Partnership Project 3GPP2 was established, focusing on the CDMA technology. 3GPP2 is thus the standardization group for CDMA2000, a set of 3G standards based on earlier 2G CDMA technology.

Based on the collaboration agreement in December 1998, 3GPP and 3GPP2 bring together a number of leading telecommunications standards bodies, which are known as "Organizational Partners". There are currently six Organizational Partners in 3GPP and five in 3GPP2, as shown below. These "Partnership Projects" enjoy the benefits of a collaborative effort, including speedy working methods/procedures and faster delivery of output. They also receive the recognition as a specifications-developing body. The status provides them easier access of the outputs after transposition of the specifications into a standard and submittal via the national process into the ITU.

Table 3.12: Organizational Partners and Member Companies of 3GPP, 2005

Organizational Partner	Home Country/ Region	Number of Individual Members	Examples of Member Companies
ETSI: European Telecommunications Standards Institute	EU	211	Nokia, Alcatel, Ericsson, Vodafone, Motorola, IBM, Agilent, Nortel, Siemens, Thomson, Docomo Europe, Freescale Semiconductors, Orange, Texas Instruments, Oracle
ARIB: Association of Radio Industries and Businesses	Japan	23	Anritsu Corporation, Dai Nippon Printing, Fujitsu, Matsushita Electric Industrial, Mitsubishi Electric, NEC, NTT, NTT DoCoMo, Panasonic Mobile Comm., Seiko Epson, SHARP, Sony Ericsson Mobile, Toshiba, Yokogawa Electric
ATIS: Alliance for Telecommunications Industry Solutions	USA	16	Cingular Wireless, Digital Fountain, Kineto Wireless, Lucent, National Communications System, NextWave Telecom, Nokia Telecomm., Nortel Networks, Polaris Wireless, SBC Communications, Telcordia Technologies, T-Mobile USA
CCSA: China Communications Standards Association	China	9	Alcatel Shanghai Bell, CATT, China Mobile Com., HuaWei Technologies, Nanjing Ericsson Panda, RITT, Shanghai Research Center, TD Tech, ZTE
TTC: Telecommunication Technology Committee	Japan	8	Fujitsu, KDDI, Mitsubishi Electric, NEC Corporation, NTT DoCoMo, Oki Electric Industry, Panasonic Mobile Communication, SOFTBANK BB
TTA: Telecommunications Technology Association	Korea	7	ETRI, KT Freetel, LG Electronics, LG TeleCom, Nextreaming, Samsung Electronics, SK Telecom

Source: Adapted from 3GPP website, www.3gpp.org

Notes: While most company members of the above standards bodies are based in the home country/region, some companies participate in more than one of the above standards bodies. Conversely, many ETSI members have their headquarters outside Europe.

Table 3.13: Organizational Partners and Member Companies of 3GPP2, 2005

Organizational Partner	Home Country/ Region	Number of Individual Members	Examples of Member Companies
ATIS: Alliance for Telecommunications Industry Solutions	USA	56	Apple Computer, Cisco, Ericsson, HP, Lucent, Motorola, Nextel, Nortel, Qualcomm, Sprint, Texus Instruments, Verizon Wireless, VIA Telecom
ARIB: Association of Radio Industries and Businesses	Japan	7	Comverse, eAccess, Fujitsu, KDDI, Kyocera Corporation, Panasonic Mobile Communications, Tokai
TTA: Telecommunications Technology Association	Korea	7	ETRI, KT Freetel, LG Electronics, LG TeleCom, Nextreaming, Samsung Electronics, SK Telecom
CCSA: China Communications Standards Association	China	5	Alcatel Shanghai Bell,, China Unicom., HuaWei Technologies, Nanjing Ericsson Panda, Research Institute of Telecommunication Transmission (RITT), ZTE
TTC: Telecommunication Technology Committee	Japan	5	Access, Hitachi, NEC, Oki Electric Industry, Openware Systems Japan

Source: Adapted from 3GPP website, www.3gpp2.org

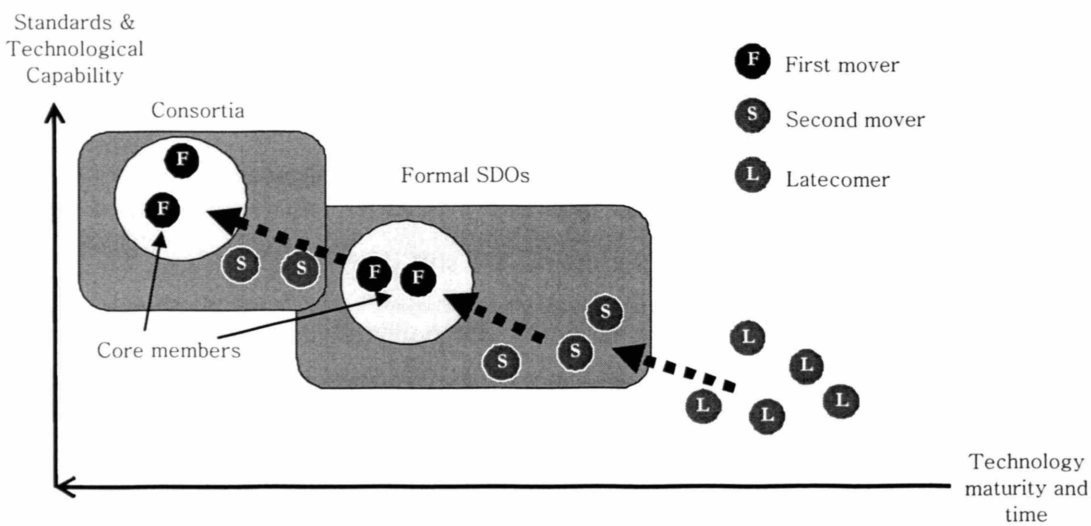
As shown in Tables 3.12 and 3.13, two Organizational Partners are standards organizations from latecomer countries, namely, the Telecommunications Technology Association of Korea (TTA) and the China Communications Standards Association (CCSA). Latecomer firms participate in 3GPP and 3GPP2 as Individual Members, under the eligibility requirement that they have to be member companies/institutions affiliated with one of the 3GPP/3GPP2 Organizational Partners. Their participation in these two prominent consortia not only indicates their effort in international standardization, but also reflects the acceptance of their increasing importance by the forerunners, i.e., the United States, the European Union and Japan. This was confirmed in our interview with an official at Korea's Telecommunication Technology Association (TTA).

CONCLUDING REMARKS

While international standardization arenas are still dominated by firms from developed economies, we see in recent years the ascent of late standardizers from emerging economies. A small, yet increasing, number of latecomers, notably from South Korea, China, and Taiwan, have emerged as fast followers and even standards leaders at the global level. Their active participation in international standardization is an important indicator of their improvement in efforts and capabilities in late standardization and technological catch-up. Some latecomers are active followers, who learn about emerging technologies through standardization activities. Others are active participants in standards development, who provide technical inputs that become part of new standards. A few of them are truly standards leaders, as they influence the directions of standards to reflect their strategic interests.

The types of standards forums that late standardizers participate are associated with their levels of technological and standards capability. As shown in Figure 3.4, latecomers at the catch-up stage generally do not participate in external standardization activities. They normally just adopt standards that are developed by technological leaders. Once they develop their technological capabilities and become fast followers, they become more involved in international standardization. This is particularly the case in "informal" standards consortia and alliances, where emerging technologies and standards are discussed and decided.

Figure 3.1: Technological Capability and Types of Standards Organizations



However, fast followers are not the core members of the standards clubs; they are there to observe and learn about technological trends and possibly connect with technological leaders. The actual standardization is driven mainly by the core members, which are usually large firms with advanced technologies. These technological leaders usually assign their employees to participate in standards forums not just as participants, but also as secretariats of technical committees, or even as board members of the organizations, such that they can influence standardization outcomes. Late standardizers thus aspire to become part of the elite core groups. However, such aspiration cannot be fulfilled easily. As we will show in our case studies in Chapters Five and Six, not every firm is able to become a core member of standards clubs. It also takes a long time before a newcomer is recognized and accepted by other firms in the standards club, even if the newcomer's technologies are technically superior. In addition, core members are likely to hold the "essential" patent technologies that underlie the standards. These core members increasingly pool their patents together to form "patent pools" or to establish cross-licensing agreements just among the core members. We will discuss this issue in Chapter Six.

Despite the difficulty, the efforts are worthwhile. Through their participation in standards forums, late standardizers create leverages for their technological upgrading and market penetration in the world market. How late standardizers use standards and participation in standardization as a mechanism to move beyond catch-up is our topic of the next chapter.

CHAPTER FOUR

STANDARDS AS STRATEGIC LEVERAGE

In each stage of late standardization and technological catch-up, latecomer firms enjoy competitive advantages derived from different sources and mechanisms. The transitions from one stage to another are in effect the changes in mechanisms and sources of their competitive advantages. Through case studies of Korean late standardizers in the semiconductor and mobile telecommunications industries, we argue that standards activities are an important mechanism that enables late standardizers to move from one competitive position to another. Using our staged model as the basic analytical framework, we demonstrate how standards function as a leverage mechanism for late standardizers to develop from being latecomers to fast followers and finally to first movers. Two specific apparatus function as the leverage mechanism, namely, Linking and Learning apparatus. The two closely-related apparatus allow late standardizers to overcome their unique constraints as latecomers, including inadequate resources and capabilities and limited access to lead-user markets and specialized inputs. Standards are an integral part of what Mathews (2002) calls the strategy of "competitive complementarity", in which latecomers complement the strategies of incumbents rather than confronting them as part of the effort to upgrade their competitive positions.

As a Learning apparatus, standards codify and diffuse technological information in the form of technical specifications, which latecomers firms can utilize without having to "reinvent the wheel". Standards and technical regulations also contain market-access information that latecomers can learn in order to export their products to advanced markets. For fast followers, participating in standards development allows them to learn about emerging technologies. They acquire information as to what technologies to expect in the near future, even though they do not yet have proprietary technologies that they can contribute to the standards. This information is critical to their ramp-up capability, their main source of competitive advantage. Fast followers then invest heavily in R&D such that they can become technology leaders even in niche technical areas. Once they have established themselves as first movers, successful late standardizers acquire ideas about competitors' R&D and product development through external standardization activities.

As a Linking apparatus, standards allow latecomers to connect with forerunners, so that they can leverage their limited resources and capabilities for more knowledge and expertise. By adopting certain standards and technical specifications, either as part of outsourcing, second-sourcing,[19] or original equipment manufacturing (OEM) contracting, latecomers and fast followers establish external linkages with forerunners. Meanwhile, quality control and management standards help latecomers to improve their production and project execution capabilities and to maximize the value of their internal resources. As latecomers, by necessity, compete in markets with mature products and technologies, the basis of competition is cost. Latecomers' competitive advantage is generally determined by production costs and quality of products. Quality standards are thus critical to their competitiveness. Throughout the process of late standardization and catch-up, quality management and standardization is a key to building a basic mechanism to move beyond catch-up.

Once latecomers produce products with quality and reliability acceptable to the world market, they become part of global production and value chains. By this time, they have improved the technological and standards capabilities beyond the catch-up stage. As fast followers, they often connect with vendors and technology leaders in standardization venues. Through repeated utilization of standards as Linking and Learning apparatus, latecomers leverage their limited resources and capabilities to develop further.

As late standardizers progress closer to the world technological frontier, their standardization efforts focus more on new specifications of products and/or processes. Even though quality standards remain important, late standardizers give additional effort to developing new product standards. The reasons are twofold. First, these firms have already accumulated standards capability related to quality control and management during their catch-up and keep-up stages. They already have competitive advantage derived from production capability. Second, as technology leaders, they compete in the market in which the basis of competition is functional product performance, rather than cost. At this stage, late standardizers compete on the basis of value, derived mainly from new product functions, rather than on the basis of costs as in the case of mature products. New standards and specifications that create market value thus become the sources of competitive advantage.

Successful late standardizers also adjust their organizational structures to accommodate standards activities. Late standardizers organize their R&D teams in such a way that standards-related activities are a core part of R&D. They also adjust internal human-resource structures, such that standards personnel stay longer in one department, rather than changing roles from one department to another. The underlying rationale is that standardization requires constant and persistent external relations with other firms in standards forums. Personal connections become critical for late standardizers who aspire to establish their foothold in standardization arenas, such that they become standards leaders themselves.

As late standardizers develop more technological capability, they integrate standards activities with intellectual-property-related activities. As firms invest more in R&D and are able to produce more intellectual property than before, they search for ways to generate and appropriate rents from their proprietary technologies. One important mechanism is to develop standards that include their intellectual property. Legal capabilities, especially those related to intellectual property, thus become a crucial part of standards capabilities. In fact, successful late standardizers have established intellectual property licensing as a separate profit-and-loss business, not just part of their legal departments.

As late standardizers become technology leaders, standards become an integral part of strategic technological management. Firms face strategic issues in developing and adopting the right standards that later become industry standards. This requires insightful and capable technology management. The importance of strategic standards management is demonstrated in our case studies of Samsung Electronics and other Korean firms in the semiconductor and mobile telecommunications industries.

In this chapter, we first review the concept of competitive advantage and order of market entry. The aim is to set the context for the subsequent discussion on how standards function as a propelling mechanism for late standardizers to move from one competitive position to another. We focus on the roles of standards as Learning and Linking apparatus that latecomers can employ to leverage their limited resources and capabilities. Our conceptual discussion in this chapter is followed by the case studies of Korean latecomers in the semiconductor and mobile telecommunications industries in Chapters Five and Six.

COMPETITIVE ADVANTAGE AND ORDER OF MARKET ENTRY

A competitive advantage is defined as a firm's ability to generate higher profits than rival firms in the same industry (Porter 1985). Competitive advantage is measured by economic rent, i.e., the profit that is higher than the cost of capital employed in the industry. Thus, the objective of a firm is to increase its economic rent, rather than its profit as such. Attaining and sustaining a competitive advantage is a key objective of any firm's business strategy.

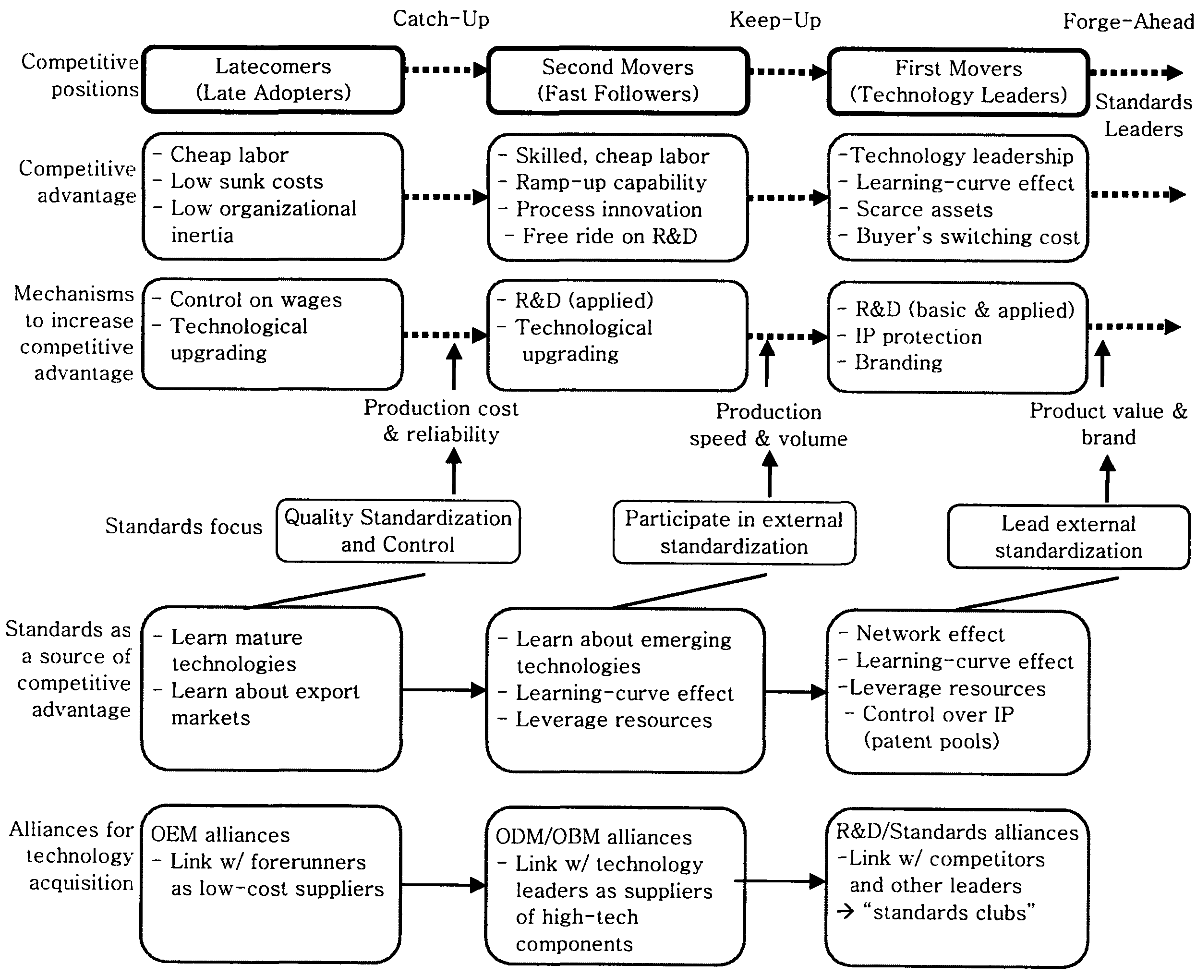
According to Porter, there are two basic types of competitive advantages: cost advantages and differentiation advantages. Cost advantages exist when the firm is able to provide the same level of benefits as its competitors but at a lower cost. Differentiation advantages, on the other hand, exist when the firm offers products that have greater benefits than the competing products. Competitive advantages thus enable the firm to create greater value for its customers, which result in greater profits for itself.

Firms can create competitive advantages by using resources and capabilities to attain either a lower-cost structure than the competitor or a differentiated product. They position themselves in their industry through their choice of either low cost or differentiation. This is a strategic decision that firms have to make in devising their competitive strategies. They also have to make decision as to how broad a market segment to target.

Cost and differentiation advantages are considered "positional advantages", as they indicate the firm's position in the industry as a leader in terms of either cost or differentiation. While there are several factors that affect positional advantages, it is widely accepted in the industrial economics literature that firms could acquire competitive advantages according to their order of market entry (Lieberman and Montgomery 1988). The literature focuses primarily on two orders, i.e., first-mover and second-mover positions. In the context of technological catch-up, another order of market entry is possible, that is, latecomers.

We can think of technological catch-up as a process in which latecomer firms develop from a latecomer position to a second-mover/fast-follower position, and finally to a first-mover/technology-leader position. Such process is characterized by the changes in competitive advantages that firms enjoy. While latecomers' main sources are low costs for various factor inputs, such as labor and labor-intensive materials, second movers gain competitive advantage from ramp-up capability and high-skilled labor at relatively low costs. First movers gain their competitive advantage from technological leadership, buyers' switching costs, network effects, and learning curve effects. Standards and related activities are important because they serve as the mechanism that propels latecomers to move from one competitive position to another. Put differently, standards allow firms to capture rents from different mechanisms and sources of competitive advantage. Figure 4.1 illustrates the conceptual connections between late standardization, competitive positions, and order of market entry. Specifically, we discuss the three market-entry orders, the associated competitive advantages, the general mechanisms to capture such advantages, and how standards serve a source of competitive advantage in each stage.

Figure 4.1: Late Standardization, Competitive Advantage, and Order of Market Entry



FORERUNNERS: FIRST-MOVER ADVANTAGES

The idea that order of market entry may affect firms' competitive advantage has long existed in the economics literature. As early as 1934, Von Stakelberg (1934) demonstrated that a leading firm was able to capture a larger market share and higher profits than a follower. Since then, many analysts in the fields of industrial economics and strategic management have examined the factors and mechanisms that explain first- and second-mover advantages.

In their conceptual survey on the issue, Lieberman and Montgomery (1988) identified four types of mechanisms that enable firms to sustain first-mover advantage: (1) technological leadership, (2) preemption of scarce resources, (3) customer switching costs, and (4) network effects. We discuss each of these mechanisms with specific reference to standards.

(1) Technological leadership

Firms can capture first-mover advantages through sustained technological leadership. Two basic mechanisms allow firms to sustain such advantages, namely, learning curve effects, and R&D and patents. As shown in the standard learning-curve model, average production costs fall with cumulative output. Early entrants can gain substantial cost advantages if their learning can be kept proprietary and their leadership in market share maintained. Similar effects apply to the case of cumulative investment, instead of cumulative output (Gilbert and Harris 1984). The learning curve thus generates substantial barriers to entry.

First movers can also gain advantages over second movers if technological advantage is a function of R&D expenditure and technology can be kept proprietary through patents or trade secrets. The level of first-mover advantage depends significantly on the appropriability regime. The more difficult it is for other firms to imitate the technology, the greater the advantage is for the innovators to enjoy. Innovations that induce first-mover advantages include not only product innovations, but also organizational and managerial innovations (Chandler Jr. 1977; Teece 1980).

First movers may use standards as a way to sustain its technological leadership. Because standards are developed by "clubs" of companies, the club members learn beforehand what technologies are likely to be the next industry standards. The learning curve effects are thus derived from their participation in standardization activities. Furthermore, the use of strict intellectual property protection linked to standards, such as patent pools, helps sustain the first-mover advantage due to technological leadership.

(2) Preemption of scarce resources

First movers may capture advantages over second movers by preemptively acquiring scarce assets. Such assets could be naturally scarce resources or other process inputs. Or they could be positions in "space", including geographic space, product space, shelf space, etc. As Ricardo (1817/1963) demonstrated using the case of productive land, preemptive acquisition of scare resources allows first movers to capture greater economic rents than second movers.

Under many circumstances, standardization is closely related to allocation of scarce resources. One good example is standardization of mobile communication technologies that use radio frequency. In several ITU committees, advanced economies push for speedy standardization of certain technologies. In contrast, developing economies want to delay the standardization process, because they fear that there would be no frequencies left for them in the future when their technological capability is good enough to utilize the technology.[20] Allocation of a scarce resource – in this case, radio frequencies – would give developed economies the first-mover advantage through preempting such scarce resource.

(3) Buyer switching costs

Another mechanism that gives rise to first-mover advantages is buyer switching costs. Late-movers have to overcome additional barriers to attract customers away from the products or services offered by first movers. Switching costs arise from various sources. One source is the initial transaction costs or investments that the customer makes when adopting and adapting to the first mover's product. Another source is supplier-specific learning by the customer. As the buyer adapts to the specific characteristics of the product offered by the supplier, switching to another supplier may appear to be too costly for the buyer. Another source of switching costs is contractual, in that it was created by the seller when the transaction was first made, so as to prevent the buyer from switching to other suppliers. Lastly, imperfect information regarding product quality may prevent buyers from switching to new products offered by second-mover firms.

Standards increase buyers' switching costs to different degrees, depending on how widely they are adopted by the market. Once buyers have chosen certain standards, they tend to keep using the standards until the alternatives become convincingly more attractive.

(4) Network effects

Network externalities add to the advantages of first movers. As discussed in Chapter Two, when there are incentives for users to adopt products that are interconnected or compatible with one another, first movers may enjoy advantages over second movers if the installed base is large enough (Farrell and Saloner 1986; Katz and Shapiro 1986). Standards, particularly compatibility and interoperability standards, add network effects to the products, if they are used in conjunction with other products/components in the systems under the same standards.

FAST FOLLOWER: SECOND-MOVER ADVANTAGES

Also known as late-mover or late-entrant advantages, second-mover advantages are, in effect, first-mover disadvantages. While first movers may enjoy many advantages over second movers, they are also faced with potential disadvantages of being the first. As Lieberman and Montgomery (1988) identify, second-mover advantages arise from various sources, as follows:

(1) Free-rider effects

Second movers may be able to free-ride on the first mover's investments in various areas, such as R&D, buyer education, and infrastructure development. Information and knowledge spillovers may enable second movers to free ride on first movers' R&D and learning experiences. Although diffusion of technology may occur through markets in the form of technology licenses, much diffusion occurs without market transactions between first- and second movers. Labor mobility, research publications, informal communication, and reverse engineering are some of the modes through which second movers can learn from first movers without investing in R&D.

In the case of standards, second movers do not have to "reinvent the wheel" and just free-ride on first movers' investment in standards development. As standards development requires a large investment, free-riding could result in substantial advantage for second movers. The difference between second movers and latecomers lies in the speed of their learning. Second movers are fast followers, who learn what technologies are emerging. As these emerging technologies mature and the profit margins fall rapidly, the technology owners become more willing to license them out. As soon as this happens, second movers jump right in and use their ramp-up capability to generate revenues from low-margin products.

(2) Resolution in the market of technological or market uncertainty

Technological and market uncertainty increases the advantage that second movers may gain from being late to the market. By entering early in an uncertain market, the first mover has to deal with a high degree of risk, while second movers can wait and see. Second movers can also learn from the mistakes that the first mover has made in various aspects of the product, including consumer preferences and regulations involved.

However, as Wernerfelt and Karnani (1987) demonstrate, first-mover firms may gain advantages even under uncertainty, if they can influence how technological and market uncertainty is resolved. Setting industry standards, either de jure or de facto, is one way of influencing such resolution. This makes it even more important for second movers to participate in standardization activities, even if they do not have proprietary technologies. This tactics, of course, depends on whether or not first movers realize this tactics and prevent them from joining the standards clubs in the first place.

(3) Shifts in technological paradigms and consumer needs

Changes in technological paradigms could create opportunities for late-movers to enter the market and become the new “first movers” themselves (Dosi 1982; Perez and Soete 1988). As Schumpeter (1942) argues, innovations lead to the “gales of creative destruction" as innovations caused old inventories, ideas, technologies, skills, and equipment to become obsolete. Because the new dominant technology often appears when the market for the old technology is still expanding, first movers may not be able to foresee the threat of the new technology and respond accordingly (Lieberman and Montgomery 1988). Standards forums are often the venues where possible future technological paradigms are presented and discussed. It thus makes sense for both first- and second movers to participate in such forums to learn about the new technological paradigms.

(4) Incumbent inertia

First-mover advantages may be diluted by the inflexibility incurred by the firm's existing investment and organizational structure. The firm may be reluctant to divest its fixed assets, and thus continue using the old technologies. It may also be slow to introduce innovation to the market, fearing that this may affect the existing product lines that contribute to the firm's profits and growth. Furthermore, its organizational structure may be too rigid for the firm to respond to the changing competitive environment. Inter-organizational routines, internal political dynamics and stable external relationships with other firms are also the factors that contribute to organizational inertia of the first mover. Second movers may be more advantageous, if they are able to recognize these issues and avoid falling into the same trap.

LATECOMER ADVANTAGES

Conceptually, latecomers from late-industrializing countries are different from late-movers from advanced economies in that they have to overcome several additional entry barriers (Hobday 1995; Mathews and Cho 2000; Mathews 2002). First, latecomers are "late" by necessity, not by choice. Latemovers may deliberately choose the strategy to enter the market late, despite having appropriate capabilities and resources. But latecomers have no choice but to enter the market late, because of their lack of technologies and resources. Second, latecomers have to overcome the distance to the lead-user markets and the leading sources of technology, most of which are located in developed economies. Third, they have to overcome the lack in specialized inputs, such as high-tech engineers and scientists, as well as supporting infrastructure for research and development. Fourth, their strategic intent focuses on catching up with forerunners. The goal of a latecomer firm is thus to graduate from being a latecomer as fast as possible, and to become a player in the industry, so that eventually it is able to choose strategically whether to be a first mover or a late mover.

As latecomers are conceptually different from late movers, the sources and mechanisms of competitive advantages that they enjoy are also different. The main source of advantage that latecomer firms have initially is low costs for various factor inputs, such as labor and labor-intensive materials. Other sources include protected markets that allow local firms to nurture their technology without direct competition against leading firms. Latecomer firms may also benefit from the technology that advanced firms are willing to transfer in exchange of their market access to the latecomer firms' domestic markets. Furthermore, latecomer firms may benefit from the information asymmetry advantage vis a vis leading firms, as information about their capabilities and sources of technology is less available to outsiders (Wong 1999).

COMPETITIVE ADVANTAGE AND RESOURCE-BASED THEORY

Standards contribute to technological upgrading of latecomer firms, as they help improve firms' resources and capabilities. We can analyze this issue in the context of the resource-based theory or resource-based view of firms. Pioneered by the works of Penrose (1959/1995) and Wernerfelt (1984), the literature on resource-based theory is voluminous, including a wide range of studies on firms' competitive behavior. In a nutshell, the main argument of the theory is that rare and valuable resources enable firms to create and sustain competitive advantage. Firms can sustain such advantage as long as they are able to protect against resource imitation, transfer, or substitution.

The theory is based on the view of the firm as a collection of resources and capabilities. Resources are firm-specific assets useful for creating a competitive advantage. Resources are either tangible or intangible. Examples of such resources range from production equipment, and proprietary knowledge and know-how, such as patents and trade secrets, to installed customer base and brand equity. Although each resource may not individually result in a competitive advantage, the synergistic combination and integration of the resources may contribute significantly to the firms' competitiveness.

Capabilities, on the other hand, refer to the firm's ability to utilize its resources effectively. They are generally embedded in the routines of the firm and are not easily documented as written procedures. Capabilities are thus a form of tacit knowledge that is difficult for competitors to imitate and replicate.

Firms are also viewed to have "core competence" that determine its competitive strategy (Prahalad and Hamel 1990). Differences in firm's performances across time are driven primarily by their unique resources and capabilities rather than by an industry's structural characteristics. This perspective is in contrast to other theories on competitive advantage (e.g., Porter 1985), which focus on the firm's external competitive environment. The resource-based perspective focuses on how firms acquire and utilize their internal resources and capabilities to deal with the external market context in which they operate.

Differences among firms in terms of resources and capabilities allow some of them to gain above-average profits, i.e., economic rents. A set of criteria characterize the types of resources that help sustain competitive advantage (Dierickx and Cool 1989; Barney 1991), including:

- Valuable: when they lead to strategies that improve efficiency or effectiveness;
- Rare: when the valuable resources are not possessed by other firms;
- Non-imitable: when competitors cannot imitate due to unique historical conditions, causally ambiguity, and social complexity; and
- Non-substitutable/transferable: when there are no equivalent valuable resources available the market

The resource-based theory emphasizes strategic choices that firms make, pointing to the important tasks of identifying, developing and allocating key resources to maximize returns. It stresses that a firm's internal conditions is more critical to determining its strategic action than the external context. By focusing on its unique resources and capabilities as the basis for a strategy, the firm can better exploit its core competencies relative to opportunities in the external environment. Sustainable competitive advantage is achieved by continuously developing existing and creating new resources and capabilities in response to changing market conditions.

The resource-based theory is robust in explaining how firms in advanced economies sustain their competitive advantages. However, the theory is less applicable to latecomer firms, which face additional entry barriers. The resources and capabilities with which latecomers have to deal are different from those for advanced firms. Reformulating the resource-based theory, Mathews (2002) proposes that the latecomers leverage external resources that are imitable, substitutable, and transferable. Imitable resources are those that latecomers can replicate through various means, including licensing a product design or reverse engineering a product. Substitutable resources are those with strong tendencies towards product and process technology turnover, as in the case of short product cycles. Transferable resources are those that latecomers can purchase from independent equipment vendors, in the form of product licenses or transferable process technologies. We extend Mathews' proposition and demonstrate in the following section how standards contribute to latecomers' efforts in leveraging for such resources.

STANDARDS AS RESOURCES AND CAPABILITIES

Standards are a type of firm-specific assets, encompassing not only proprietary technological knowledge codified in written documents, but also human resources and organizational knowledge related to standards activities, as well as customer base and brand identity associated with specific standards. Standards as resources, therefore, include more than just technical aspects of the technologies and products in question.

Standardization allows latecomers to leverage external resources more easily and effectively, particularly because it increases imitability and transferability of the resources. For instance, latecomers can acquire new technologies in the form of standardized specifications from technology leaders or purchase them from independent equipment vendors. How effectively latecomers can use standards to leverage external resources depends greatly on their general absorptive capability, specifically their standards capability.

Standards capability is simply defined as the capability of an actor (individual, firm, or institution) to deal effectively with standards (Vries 1999). The types of standards capabilities include the capability to identify the needs for standards, to search and select appropriate standards, to acquire and assimilate standards into the production process, to adapt standards according to local conditions, to modify standards in response to changing economic conditions, and to develop new standards for internal and external uses. While all types of capabilities are important, their levels of sophistication vary. For instance, the capability to develop and set standards based on proprietary technologies requires more advanced capability than the search-and-select capability. It requires not only advanced technological capability but also the ability to deal with other firms and institutions in the market.

Standards capability is also as a measure of technological capability of a firm or a nation. However, standards capability is more than just technical capability. It involves additional organizational, institutional, and legal capabilities. As we will show in the case studies of Korean late standardizers, as firms move closer the world technological frontier, organizational and legal capabilities become more critical to successful standardization efforts. Firms need to be able to organize their workforce and knowledge related to standards, and protect intellectual property rights related to standards.

STANDARDS AS LEVERAGE: LINKING AND LEARNING

In examining the roles of standards and related activities as a mechanism for latecomers to move beyond catch-up, we use the analytical framework built upon the concept of "resource leverage" as found in the strategic management literature (e.g., Ghoshal 1987; e.g., Hamel and Prahalad 1993) and expanded to explain late standardizers (Mathews 2002). Leverage refers to the effort by the firm to acquire resources beyond its boundary, while enhancing its absorptive capability once such new resources are acquired (Hamel and Prahalad 1993;

Mathews 2002). In the case of latecomers, leverage is an effort to overcome their limitation in their initial internal resources and capabilities (Mathews 2002).

As indicated by the wide acceptance among the strategic management literature, the resource-based approach has been successful in explaining how firms sustain their competitive advantages. However, as Mathews (2002) argues, the theory is less successful in elucidating how firms with limited resources manage to create advantages in the first place so that they can overcome incumbent advantages. Mathews points to the strategy of "competitive complementarity" in which latecomer firms complement the strategies of forerunners rather than confronting them, so that they can leverage their resources through linkages with the forerunners. By repeating linkage and leverage activities, latecomers learn and accumulate various types of knowledge for developing technological and organizational capabilities.

How do latecomers use standards to leverage resources at each stage of the late standardization process? In answering this question, we use an analytical framework similar to that of Mathews. In our framework, however, Linking and Learning are the two apparatus that latecomers employ as part of the leverage mechanism. We argue that late standardizers use standards and related activities as a way to establish linkages with forerunners and other firms, and to learn about their technologies, such that they leverage the external sources of resources and capabilities.

The use of standards as a mechanism to move beyond catch-up is distinct in each stage of late standardization. First, during the catch-up stage, latecomers use standards as a leverage mechanism to enter mature industries. As latecomers do not have cutting-edge technologies, they enter the industries in which standardization has already been achieved. As one function of standards is to enhance price competition, standardization makes products more compatible with one another and further enlarges the market. This benefits latecomers as low-cost producers. Examples abound in which latecomers enter international markets by selling standardized products. Latecomer firms can also apply internationally accepted specifications to the development, manufacturing and marketing of local goods and services to raise their competitiveness in the export markets. Standardization thus facilitates the integration of latecomers' manufactured exports into the world market.

However, the benefits of using standards to leverage limited resources do not appear automatically. Latecomers, in practice, have substantial disadvantages in using specifications of foreign and international standards, and face high adaptation costs in doing so. Because they have little influence on the development of such standards, most standards are biased in favor of the requirements of developed-country firms. The objectives of latecomers are rarely taken into account in the process of international standardization. More sophisticated standards also mean that firms in developing countries may find it more difficult to penetrate the developed-country markets. Latecomers, therefore, have to develop internal absorptive capabilities that deal with standards so as to reduce the adoption costs. Table 4.1 summarizes the benefits of standards as a leverage mechanism for latecomers to move beyond catch-up.

Table 4.1: Standards as a Leverage Mechanism through Linking and Learning Apparatus

Stage	Standards as Linkages	Standards as learning	
		Technical Knowledge	Business Knowledge
Catch-up	Cost-economizing buyer-supplier linkages: with technology leaders OEM, buyers and suppliers	Codified mature technologies	Consumer preferences
Keep-up	Cost-economizing buyer-supplier linkages: with technology leaders OEM, buyers and suppliers	Emerging technologies	Potential future customers
Forge-ahead	Strategic linkages: with competitors, vendors, suppliers	Advanced future technologies	Competitors' development plans

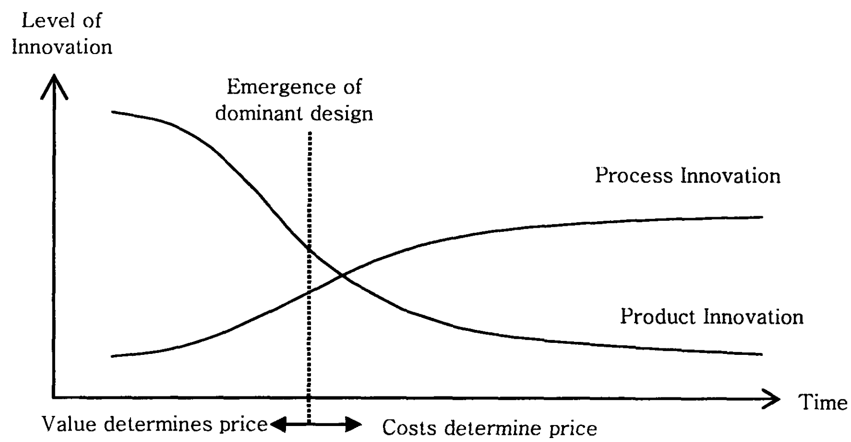
STANDARDS AS LINKING APPARATUS

Standards constitute linkages for latecomers in various ways. Standards serve as the linkages through which latecomers may extend their presence and influence into new markets or new businesses. Standards as linkages also function as a way for latecomer to extend into new cross-borders activities through interfirm relations, possibly with technological leaders. The more dense these interfirm relations, the more opportunities there are in the global economy for latecomer firms to tap into (Mathews 2002). During the stage of catch-up, latecomers, by necessity, adopt standards developed by technological leaders. The choices of standard indicate which technology leader or leaders that latecomers firms want to follow. Latecomers that are OEM suppliers accept specifications and standards required by their buyers, thereby linking their businesses with those of global players.

The use of standards as a linking apparatus depends on the source of competitive advantage that latecomers enjoy in their process of late standardization. Firms generally gain competitive advantage and capture rents either from high value or low cost. In the Abernathy-

Utterback model of innovation dynamics, during the fluid stage before the dominant design or standards are fixed, prices are usually determined by product values derived from functional performance. Once the dominant design or standards are fixed, the competition, and hence prices, are often determined by costs of products (Table 4.2).

Figure 4.2: Determinants of Price before and after Emergence of Dominant Designs



Without advanced technologies as their source of competitive advantage, latecomers cannot compete in terms of product functions in their early stage of development. They have to compete in the mature-product markets, where products are made around some dominant designs. Price competition is fierce and pressure on profit margins is enormous. Firms need to reduce costs and increase volume of production. In order to compete in such markets, latecomers have to focus on the costs and quality of products. This gives rise to the important role of quality standardization and management. Latecomers have to commit to firm-wide improvement in efficiency from production to distribution. Quality management and standardization becomes the key for latecomers to go beyond catch-up. As latecomers are able to produce mature products with quality and reliability, they become part of global value chains. This linkage is the first step towards being accepted by the existing leaders and the first step to be eventually allowed to join the standards club. Late standardizers need to focus first on quality and reliability in process and production.

Once latecomers develop into fast followers, they establish linkages with technology leaders not only through adopting the actual standards themselves but also through participating in external standardization activities. Here, they acquire the opportunity to connect with forerunners in the industry through common standardization efforts. Standards allow latecomer firms to "network" with leading multinational companies. As Cho and Lee (2003) argue, networking capabilities are an important factor for technological catch-up in the globalization era. Linkages that latecomer firms can establish through standards forums may be another channel for them to improve their networking capabilities.

Linkages established through common standards and standardization efforts allow firms to leverage their R&D assets through strategic alliances. Such strategic alliances allow late standardizers not only to reduce risks and costs of R&D and improve their appropriability of their innovation, but also to acquire market access and complementary assets and resources that they do not possess in-house (Narula and Hagendoorn 1999). As Penrose (1959/1995) and Teece (1980) argue, internal economies of scope arise when there are excess capabilities in the organization that can be usefully applied to new activities that are similar to the ones in which the firm has already engaged. Quality standards and tools help create such economies of scope externally for latecomer firms by linking them with other firms.

Standards and related efforts function as a Linking apparatus slightly differently for late standardizers at the forge-ahead stage that have substantial R&D capabilities. As late standardizers develop internal R&D resources and capabilities, they face an additional challenge; they have intellectual property that needs to be used in one way or another to justify the R&D investment. While many standards are eventually open for public use, most industry standards contain technologies proprietary to firms. One of the main motives behind firms' engagement in technical standardization is thus to gain control over future generations of technology, such that their proprietary intellectual property is included in standards. Advanced late standardizers often build linkages with their competitors, vendors, or buyers in the form of strategic alliances, for instance, in the form of standards clubs. The main motivation behind such strategic alliances is not short-term cost economization, but long-term profit optimization (Narula and Hagendoorn 1999). Therefore, late standardizers at the forge-ahead stage consider standards as part of their long-term R&D and/or corporate strategies.

STANDARDS AS LEARNING APPARATUS

Standards serve as a Learning apparatus for late standardizers in various ways. Through standards, late standardizers acquire two general types of knowledge from external sources: technical knowledge and business knowledge. While latecomers acquire both types of knowledge during the late standardization process, the levels of complexity and novelty of technical knowledge vary greatly at different stages of late standardization (see Table 4.18). During the catch-up stage, latecomers acquire knowledge about mature technologies, as well as consumer preferences and market-access information, through standards and technical regulations. Fast followers then learn about emerging technologies, as they participate directly in external standardization activities. For advanced late standardizers that are technology leaders, the knowledge about competitors' technologies as well as product development plans have important strategic implications for them.

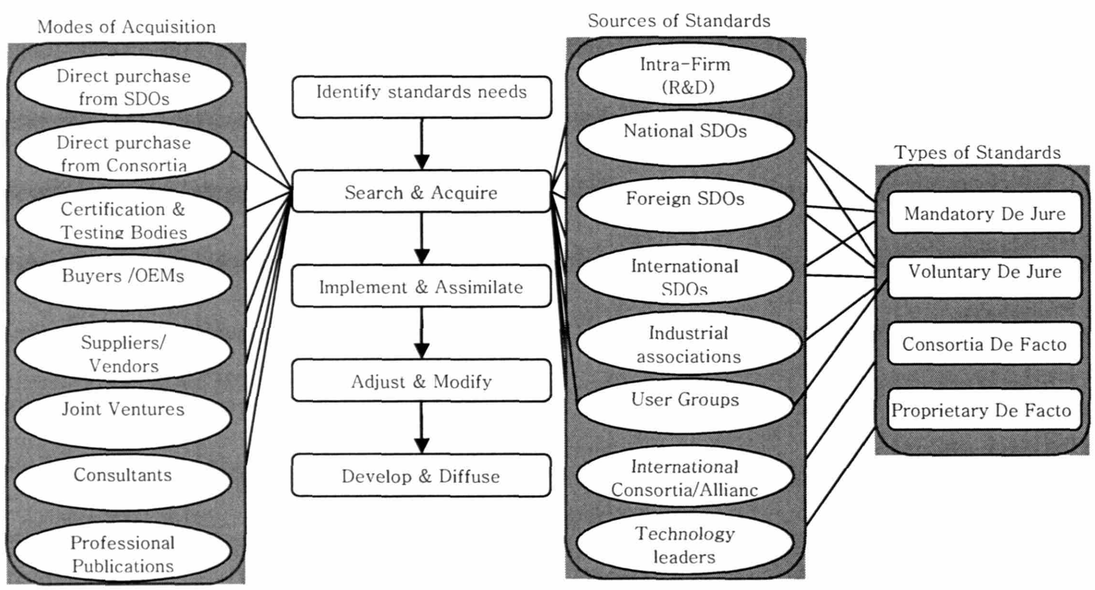
Late standardizers learn from standards through various modes. One is through studying the written standards themselves, which are in effect a codified form of technical knowledge. Another mode is through participating in standardization processes, in which technical knowledge is not yet codified but in the codification process.

Standards as codified technical knowledge

Standards are a form of codified knowledge. By adopting existing standards, latecomers are able to learn about the technologies codified such standards without having to invest heavily in R&D. They can avoid the waste of resources by not having to "reinvent the wheel." Technical specifications described in standards are important sources for technical knowledge and know-how for latecomer firms. As many standards are often publicly available, or can be purchased from standards organizations, they can be used, in principle, by any firm. This means, at least theoretically, that products based on these standards may be produced at any locations that are not the original source of innovation. Latecomer firms can thus benefit greatly from knowledge codification that occurs during the standardization process.

Latecomers may learn various subject matters from standards. These include: (1) a set of nomenclature or definition of terms, (2) specifications for the quality, composition, or performance of a material, an instrument, a machine, or a structure, (3) sampling or inspection methods to determine conformity with a specified requirement of a large quantity of material, (4) testing methods to evaluate specified characteristics of a material or chemical, (5) a scheme of simplification of variety of sizes, shapes, or grades, (6) a code of practice for design, construction, operation, and safety, and (7) a model form of contract or agreement (United Nations 1964). As in technology acquisition in general, the selection of types, modes, and sources of standards by latecomer firms is often strategic and depends on the firms' capabilities and constraints. The standards that latecomers adopt are usually mature standards, or are based on mature standards established by technological leaders.

Figure 4.3: Sources and Modes of Standards Acquisition



Notes: SDOs stands for Standards Development Organizations.

As shown in Figure 4.2, several sources are possible from which latecomers can acquire standards. These include formal external sources, such as industry associations and national SDOs, and less formal external sources, such as consortia and alliances. It is very unlikely, if not impossible, that latecomer firms would use standards developed by internal sources, e.g., their research and development (R&D) departments. Therefore, in the model of late standardization, latecomer firms are assumed to start from adopting standards developed by forerunner firms and/or by SDOs. Latecomer firms may acquire the specific details of standards through various modes, including direct purchase from SDOs and consortia, technical assistance from buyers and suppliers, joint venture with foreign firms, expert consultants, and/or professional publications and conferences. In effect, these sources are *linkages* that latecomers utilize for their technological upgrading efforts.

Standards as codified business knowledge

By adopting standards developed by technology leaders, latecomers may acquire not only technical knowledge but also business knowledge. Business knowledge includes not only information about consumers' preferences and trends, but also market-access information, particularly on institutional and regulatory regimes. While many standards and regulations are mandatory by law, particularly those for safety, health, and the environment, others are voluntarily adopted by the market. Latecomers often choose to adopt voluntary standards developed by their major trading partners, so as to facilitate entry in the export markets (Stephenson 1997).

Another way for latecomers to learn from standards is by proving that their products comply with certain standards and technical regulations. Latecomers may start from selling products to domestic markets where regulations are not strict or limited in number. Then they attempt to export developed markets where standards and technical regulations are stricter and greater in number. During such process, latecomers have much to gain from learning about different institutional and regulatory regimes. While standards pose tremendous obstacles to latecomers' technological efforts, the process of learning-by-proving is indeed an important channel for them to learn and benefit from the dense thicket of standards and technical regulations (Srinivas 2004).

However, as identified in the vast literature of technological transfer, even mature technologies are not easy for latecomer firms to acquire and adopt (e.g., Lall 1993). The same is true for standards. Latecomer firms and governments may have substantial disadvantages in using specifications of mature standards, and face high adaptation costs in doing so. Because latecomers have little influence on the development of standards at the beginning, most standards are biased in favor of the requirements of the technological leaders. Their objectives, capabilities, and constraints are rarely taken into account in the process of standardization.

Learning during keeping-up and forging-ahead

Fast-follower firms acquire technical and business knowledge by participating in standardization activities. The advantages of participating in standards consortia and alliances are not limited to the knowledge about the technologies used in standards and the information regarding market access. Generally, firms that join standards consortia are more likely to gain knowledge about what technologies to be adopted in the marketplace than firms that do not join. Particularly, informal consortia and alliances are the places where rapidly-changing fields of technologies are being discussed and decided. Fast followers gain the knowledge as to what technologies are likely to be adopted by other firms and eventually in the future market. This knowledge is critical for fast followers, especially during the time when even technological leaders have to form alliances to remain competitive.

There are limited windows of opportunity, within which firms can acquire and decide on dominant design and standards. After dominant designs are decided, market demand will rise. As Christensen et al. (1998) empirically show, firms that adopt the dominant design or standards are able to exploit the rising demand more than firms that do not. We can logically extend this statement and argue that first-mover advantages are not necessarily about first-to-the market. Rather it is the first to establish the dominant design and produce products according to it. Firms that participate in standardization are able to introduce products to the market more quickly, as they have more knowledge about the future dominant design.

Standards also allow late standardizers to diversify their product lines more efficiently. Underlying this proposition are two key explanatory variables: that is, product mix and diversification pattern. As a stylized fact, latecomer firms, such as the Korean firms, have generally focused on the expansion of capacity and international market share for homogeneous, mass-produced products. They have adopted the competition strategy that focuses on product diversification into technologically unrelated areas. Once a latecomer firm reaches the limits of capacity and market share expansion for a particular product, it moves on to a new product group that permits rapid market expansion. These products are based on proven technologies and well-established standards.

However, in the process of upgrading into higher-end and growing market segments for differentiated products, latecomer firms have to deal with technical features that are still fluid and uncertain. But they generally lack the broad technological base that would allow them to gain better competitive positions through technological diversification. Technological diversification is defined as the expansion of a firm's or a product's technology base into a broader range of technological areas (Granstand and Sjolander 1992). Technological diversification would allow latecomer firms to extend its leadership into other technologically-related market segments. Participation in standards development hence becomes critical, as latecomers need to acquire the knowledge on technological trajectories as well as the generic technologies in standards which generally connect different technological areas. Late standardizers can acquire such knowledge and information by participating in meetings and conferences organized by standards consortia, where emerging technologies are discussed and debated as potential candidates for new technological standards.

Standardization as codification process of knowledge

The standardization process is, in effect, the process of codifying some of the tacit knowledge embodied in products and processes. Especially in the case of de jure standards set by standard-setting organizations, firms and individuals that participate in the standardization process have to cooperate and share some of their proprietary information and knowledge. Standards thus convert tacit, localized, and proprietary knowledge into generic, explicit technological and organizational knowledge that other firms can utilize (Antonelli 1994).

As discussed earlier, voluntary standards are non-pure private goods that are created and shared by members of a club. By participating in the standard-setting processes, each club member in effect agrees to share technical and commercial information, the use of the same pool of intermediate and primary inputs, and the resulting market demand for their products. The use of information is non-rival within the club, thus leading to more efficient production processes and higher levels of demand. Being a club member, each firm has the power to influence the final specification of the standards such that the final outcome is as close as possible to its current products and/or processes. Meanwhile, firms outside the standard-setting club would face disadvantages if they were to adopt the standards on which they have no influence. In fact, firms often use product standards as a strategy to raise the costs of their competitors (Salop and Scheffman 1987).

These propositions are applicable to the model of late standardization. Technological leaders are members of standard-setting clubs, while latecomers at the catching-stage are non-members who have to adopt the standards developed by the clubs. Forerunners enjoy first-mover advantages from adopting standards that they themselves develop, especially from learning and reputation effects, which lead to greater market shares at the early stages of product life cycles. Latecomers, on the other hand, face substantial disadvantages in entering the market, due to entry barriers and network effects caused by standards.

Standards also allow late standardizers to learn about their competitors' technological paths and product development plans.[21] This is particularly true for late standardizers that are already in the forge-ahead stage, in which functional product performance is the basis for market competition and a key factor underlying firms' competitive advantage.

Internal standardization as a way for knowledge accumulation

The knowledge that latecomers acquire through standards and standardization is not limited to that from external sources. By engaging in internal standardization activities, particularly those related to quality control and assurance, latecomers learn how to improve technological capabilities. Standardization allows firms to codify and accumulate various types of knowledge and know-how that employees repeatedly experience. Internal standards activities thus facilitate knowledge accumulation at the firm level.

As Amsden (2001) points out, three types of capabilities are crucial to technological efforts of any firm: namely, production capabilities, and project execution capabilities, and innovation capabilities. Standards contribute to the accumulation of all three types of capabilities. Through quality control and assurance practices, such as the ISO-9000 series and Six Sigma, latecomer firms learn how to improve their production capabilities. Various types of project management standards, such as Project Management Institute (PMI) standards, allow firms to learn and record their experiences, such that they can improve project execution capabilities. In sum, latecomers cannot improve their technological capabilities without engaging in internal standardization practices.

CONCLUDING REMARKS

Standards activities are an important mechanism that enables late standardizers to move from one competitive position to another. Specifically, standards function as a leverage mechanism that firms can use to move from being latecomers to fast followers and finally to first movers. Two specific apparatus function as the leverage mechanism, namely, linkage and learning apparatus. These apparatus allow late standardizers to overcome their unique constraints as latecomers, including inadequate resources and capabilities, and limited access to lead-user markets and specialized inputs.

Standards constitute linkages through which late standardizers may extend their presence and influence into new markets or new businesses through inter-firm relations, possibly with technological leaders. In a nutshell, adopting others' standards and technologies indicate the decision for what Mathews (2002) calls "competitive complementarity," in which latecomers complement the strategies of incumbents rather than confronting them as part of the effort to upgrade their competitive positions.

As fast followers, firms establish linkages with technology leaders not only through adopting standards but also through participating in external standardization activities. Here, they acquire the opportunity to connect with forerunners in the industry through common standardization efforts. Advanced late standardizers build linkages with their competitors, vendors, or buyers in the form of strategic alliances. The main motivation behind such strategic alliances is not short-term cost economization, but long-term profit optimization. Standards forums are an example of such strategic alliances.

Using standards as a learning apparatus, late standardizers acquire two general types of knowledge from external sources: technical knowledge and business knowledge. While latecomers acquire both types of knowledge during their late standardization process, the levels of complexity and novelty of technical knowledge vary greatly with different stages of late standardization. During the catch-up stage, latecomers acquire knowledge about mature technologies, consumer preferences, and institutional and regulatory regimes through standards. During the keep-up stage, fast followers learn about emerging technologies by participating in standards development. During the forge-ahead stage, late standardizers acquire knowledge about competitors' research directions and product development plans through interacting with them in standards forums, which have important strategic implications for competitive advantage.

Internal standardization practices allow firms to record and accumulate technical and business knowledge. Through quality control and assurance standards, latecomer firms learn how to improve their production capabilities. Similarly, through project management standards, latecomer firms learn and record their experiences in capacity expansion and business diversification through projects. This results in improvement in project execution capabilities. Latecomers cannot improve their technological capabilities without engaging in internal standardization practices. We now turn our attention to the case studies of Korean late standardizers to illustrate how standards serve as a leverage mechanism for them to move from one competitive position to another.

CHAPTER FIVE

CASE STUDIES OF LATE STANDARDIZERS IN SEMICONDUCTOR

SAMSUNG'S LATE STANDARDIZATION IN SEMICONDUCTOR ■ SAMSUNG AS LATECOMER ■ SAMSUNG AS FAST FOLLOWER ■ SAMSUNG AS STANDARDS LEADER ■ OTHER LATE STANDARDIZERS IN SEMICONDUCTOR ■ CONCLUDING REMARKS

Since the rise of Japan as a technological and standards leader in the 1970s, very few countries in recent decades have emerged from being technological and standards followers to leaders. Among the small number of latecomer firms that have emerged as important players in international standardization arenas, South Korean latecomers are the most prominent. They have caught up and kept up with the technological changes introduced by the forerunners in the Triad countries. Some of these late standardizers, for instance, Samsung Electronics and LG Electronics, have exhibited technological and standards leadership in several technical areas, notably in the semiconductor and mobile communication industries.

We have selected these firms as our case studies to examine empirically how they engage in standards and standardization activities, and, as a result, have emerged to become technological and standards leaders. In other words, we examine how standards and related activities enable them to move from being latecomers to become fast followers and first movers. As explained in Chapter One, we select South Korean late standardizers as our core case studies, so that we can trace their successful efforts in late standardization and technological catch-up in the past few decades. On the other hand, we select Thai latecomers as the shadow cases, from which we refine and generalize the findings from the Korean cases.

For the semiconductor industry, we focus mainly on the Semiconductor Division of Samsung Electronics, with some references to other late standardizers, such as Hynix of South Korea and Hana Microelectronics of Thailand. We pay particular attention to their experiences in JEDEC, a major semiconductor standards forum.

Our case study of Samsung Electronics in the semiconductor industry shows that standards and related activities play critical roles throughout its technological development process. Samsung's emergence as an industry leader was first manifested through its market share, then through its technological breakthrough, finally through its influence on technical standardization. The focus on quality standards and procedures has always been important since its early years of technological development. However, as Samsung moves closer to the technological frontier, external standards activities become a key factor in determining Samsung's strategy and competitiveness. Our case studies of Samsung, LG, and KT in the mobile communication industry in the next chapter also suggest that standards activities are at the heart of these firms' R&D strategies and their competitive advantage.

These successful late standardizers also adjust their organizational structures, so that standards activities become a core component of R&D strategies and policies. Samsung and LG both have human resources policies that accommodate the career growth of standards engineers such that they are continuously involved in standards activities. In the following sections, we discuss these case studies in detail, starting from Samsung Electronics, followed by Hynix of South Korea and Hana Microlectronics of Thailand.

SAMSUNG'S LATE STANDARDIZATION IN SEMICONDUCTOR

In many respects, Samsung Electronics is the most prominent latecomer firm in recent decades. Just over a decade ago, Samsung was merely a manufacturer of low-end consumer electronics under a few brand names, including Wiseview, Tantus, and Yepp.[22] Now, it is one of the most respectable companies in the world. According to Business Week's annual survey of The 100 Top Global Brands in 2005, Samsung is ranked 20th worldwide, among other top brands, such as Toyota, Nokia, and IBM. Over the past five years, Samsung has enjoyed the biggest surge in value of any Global 100 brand, with a 186% increase. In the 2005 ranking, Samsung has even surpassed Sony (28th), which had been *the* leading electronics firm for a few decades.

Founded in Daegu, South Korea, Samsung Electronics is part of the Samsung Group. As the largest and dominant arm of the Samsung Group, Samsung Electronics operates in around 58 countries and has over 208,000 workers. In 2004, Samsung posted full-year net profits of 10.8 trillion won ($10b), making it one of the most successful companies in the world.

As of 2005, Samsung Electronics operates in five business areas: namely (1) Telecommunication network: Mobile handsets and network infrastructure; (2) Digital and Home Appliances: e.g., washing machines, microwave ovens, refrigerators; (3) Digital Media: e.g., camcorders, computers, DVD-players, PDAs; (4) Liquid Crystal Display (LCD): e.g., TFT-LCDs for handheld devices, monitors, and TVs; and (5) Semiconductor: e.g., DRAMs, Flash memory, CMOS.[23] Our focus in this chapter is on Samsung's semiconductor business, in which the firm has demonstrated strong leadership in technological and standards development. We first discuss Samsung's history of technological development in the semiconductor industry. Then we focus on its engagement in semiconductor standardization, particularly in JEDEC, a major standards consortium. We examine how such activities enable Samsung to move beyond being a follower to become a leader in the industry. We pay particular attention to how standards contribute to the firm's linking and learning efforts.

SAMSUNG'S SEMICONDUCTOR BUSINESS

Among many of Samsung's products and services, the semiconductor has long been its cash cow, if not golden goose. Semiconductor businesses have been the main source of sales revenues for Samsung, accounting for 32 percent of the company's turnover in 2004. Only in the past couple of years has its semiconductor sales revenue been surpassed by its telecommunication network sales, which in 2004 accounted for 33 percent of the total turnover.[24]

Samsung Electronics is now among the largest and most profitable firms in the global semiconductor industry. As of 2005, Samsung is the world's number two after Intel, and number one in the memory market in terms of total sale revenues in 2005. As shown in Table 5.1, Samsung's market leadership in the memory market is strong in most major memory product segments, including Dynamic Random Access Memory (DRAM), Static Access Memory (SRAM), Flash memory, and Display Driver Integrated Circuit (DDI).

Table 5.1: Top Semiconductor Firms Ranked by Sales Revenue, 2005

Rank	Overall	DRAM	SRAM	Flash	DDI	Chip Equipment
1	Intel	Samsung	Samsung	Samsung	Samsung	Applied Materials
2	Samsung	Hynix	Intel	Toshiba	Renesas	Tokyo Electron
3	Texas Instruments	Micron	Cypress	AMD	NEC	ASML Holding
4	Toshiba	Infineon	AMD	Intel	Seiko Epson	Nikon
5	STMicro	Elpida	NEC	STMicro	Novatek	KLA-Tencor
6	Infineon	Nanya	Renesas	Renesas	Sharp	Canon
7	Renesas	Powerchip	Sharp	SanDisk	Himax	Advantest
8	Philips	Promos	Toshiba	Sharp	Magnachip	Dainippon Screen
9	AMD	Winbond	STMicro	Silicon Storage	Texas Instruments	Novellus
10	NEC	ISSI	Hynix Semiconductor	Macronix	Toshiba	Hitachi

Source: iSuppli Corp. 2006

Particularly in DRAM, Samsung has maintained the number one position for more than ten years, since it first surged to become the market leader in 1992 (Table 5.2). It currently occupies more than 30 percent of the total DRAM market share.

Table 5.2: Samsung's Market Leadership in Semiconductor Industry

Product	Market Share	Rank	Leader Since
DRAM	30%	1st	1992
SRAM	27%	1st	1995
Flash Memory	25%	1st	2003
LDC Driver IC	19%	1st	2002
Total Memory products	25%	1st	1993
Overall Semiconductor	6%	2nd	-

Source: Dataquest

Note: Market share data are for 2004.

Samsung is now among the world leaders in semiconductors not only in terms of market share, but also in terms of technological innovation. The company is now a technology leader in various areas, including DRAM, NAND Flash, and SRAM memory and in Display Driver

Integrated Circuit for TFT-LCD panels. Samsung's Semiconductor Division has three business units: Memory, TFT-LCD and System LSI, providing advanced solutions for the mobile, desktop computing, consumer electronics and industrial markets. Samsung has one of the broadest portfolios in the industry. This strength lays the basis for Samsung's TFT-LCD technologies, another product segment in which the firm demonstrates technological and market leadership. Samsung has also constantly increased its leadership in System-on-a-Chip devices.

Samsung's timeline in semiconductor and its standards activities

Samsung's entry into the semiconductor industry dates back to 1974 when it started wafer fabrication. It was not until the early 1980s that Samsung entered into more sophisticated semiconductor products, such as DRAM. Samsung's path of technological development can be divided into three periods, corresponding to its relative position to the world technological leader: catch-up, keep-up, and forge-ahead. The three periods also correspond to the three stages of our staged model of late standardization and technological catch-up.

As a latecomer, Samsung's catch-up stage started in the late 1970s up until around 1985, during which the firm was producing memory products with heavy reliance on foreign technologies. Samsung became a fast follower in the keep-up stage after 1985, when it managed to close its technological gaps with world leaders within months, not years as before. Samsung obtained the status of a first mover when the firm became the first in the world to develop 64K DRAMs in 1991. Samsung's standards leadership, however, did not start until 1996, when the firm became the main force behind Double-Data-Rate DRAM standardization.

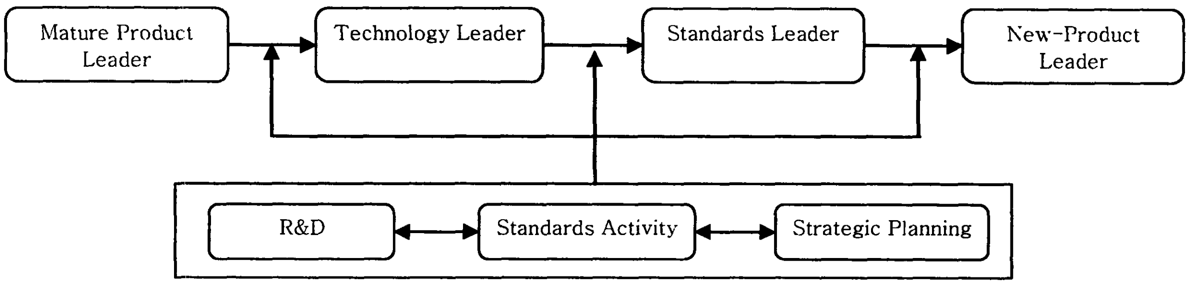
In Table 5.3, we show the timeline of Samsung's leadership in DRAM, not only in terms of market share, but also in terms of technological and standards development. Figure 5.1 illustrates the sequence of leadership that Samsung progressed through.

Table 5.3: Timeline of Samsung's Market, Technology, and Standards Leadership in DRAM

Stages	Catch-Up						Keep-Up		Forge-Ahead			
Leadership Sequence	Follower							Market leader	Technology leader		Standards leader	
Circuit Density	1K	4K	16K	64K	256K	1M	4M	16M	64M	256M	1G	4G
Initial Design Rule (µm)	10	8	5	3	1.1	0.7	0.5	0.42	0.35	0.25	0.18	0.13
Leader	Intel	TI	Mostek	TI	AT&T	Toshiba	Hitachi	Toshiba	Samsung	Samsung	Samsung	Samsung
First Developed by Leader (Year)	1970	1973	1976	1979	1982	1985	1987	1990	1992	1994	1996	2001
Technological Gap between Leader and Samsung (Years)	-	-	-	4	2	1	6 months	3 months	first	first	first	first
First Mass Production by Leader (Year)	1971	1974	1977	1980	1984	1986	1989	1991	1994	1998	2001	2003
Production Gap (Years)	-	-	-	3.5	1.5	1	0	first	first	first	first	first

Source: Adapted from Samsung Electronics website, www.samsung.com; Kim (1997); Choung et al. (2000); Shin and Jang (2005)

Figure 5.1: Samsung's Leadership Sequence in Semiconductor



CATCH-UP: SAMSUNG AS LATECOMER (1974-1985)

Samsung first gained the necessary technologies to enter the semiconductor industry by acquiring Korea Semiconductor, the first Korean semiconductor firm, in 1974. Korea Semiconductor was founded by Ki-Dong Kang, a Korean engineer who had a Ph.D. from Ohio State University and experience in semiconductor design at Motorola (Kim 1997). Samsung engineers learned greatly from Dr. Kang about semiconductor design and production. This made it possible for Samsung to start limited-scale production of transistors and integrated circuits, although with low yield ratios, for its in-house production of consumer electronics. To enable its technological capability, Samsung established the Semiconductor R&D Laboratory in 1982. The R&D Lab focused primarily on reverse engineering bipolar and metal oxide semiconductors (MOS) and assimilating the technologies into Samsung's production processes (Kim 1997).

Samsung's technological effort expanded greatly in 1983 when it increased investment in very-large-scale integrated circuits (VLSI) production. Instead of following the existing technological path of progressing from 1K DRAM to 4K DRAM and to 16K DRAM, Samsung entered directly into the development and production of 64K DRAMs. This was contrary to the position of the government, which argued for Korean firms to start from 1K DRAMs and move up to more sophisticated memory products (Lee and Lim 2001).

Samsung was able to skip some of the earlier steps in the technological path, partly because it managed to secure necessary technologies from external sources. In fact, Samsung's technological development in the 1970s and early 1980s was characterized by its heavy reliance on foreign suppliers for necessary technologies. This effort was not free of obstacles. Leading foreign producers, such as Texas Instruments and Motorola in the United States, and NEC and Hitachi in Japan, refused to license the 64K DRAM technologies to Samsung. After an extensive search by a task force team, Samsung was able to identify a number of semiconductor firms, from which Samsung could acquire VLSI technologies. Eventually, Samsung purchased the design for high-speed MOS process from Zytrex and licensed 64K DRAM designs and CMOS process technology from Micron Technology (United States) and Sharp (Japan) (Kim 1997). The licensing agreements included training programs in which Samsung's engineers were sent to these technology suppliers. These programs contributed significantly to the firm's capability to assimilate the advanced technologies into Samsung's design and production processes.

With its extensive experiences for eight years in producing transistor and integrated circuits, Samsung was able assimilate the new VLSI technologies acquired from the foreign sources into its production operation with the yield ratio as high as 92 percent, the level achieved only by leading Japanese firms (Kim 1997). The impressive production capability was the result of Samsung's relentless R&D efforts. The highlight of the efforts was the two

R&D teams that worked collaboratively in assimilating and commercializing the 64K DRAM. One of the two R&D teams was established in 1983 in Silicon Valley, the strategic location for the semiconductor industry. This R&D outpost allowed Samsung to gain knowledge about new technologies through various modes, including recruiting experienced engineers from other semiconductor firms and training of its engineers in Silicon Valley. The other R&D team was established in Korea, led by engineers who had experiences in LSI and VLSI technologies at leading U.S. firms. The collaboration between the two groups through training, joint research, and consulting, facilitated effective knowledge transfer from Silicon Valley to the team in Korea.

Samsung was finally able to develop its first 64K DRAM in 1983 and started selling the chips in the market in 1984, about forty months after Texas Instruments, the world pioneer, and about eighteen months after the first Japanese version. After its success in developing a 64K DRAM, the firm mounted its technological efforts in designing its own design technology for the next-generation 256K DRAM. Fully utilizing its R&D outposts in Silicon Valley, as well as the accumulated knowledge on process technologies, Samsung eventually was able to develop a 256K DRAM in 1984, about 2 years behind AT&T (Western Electric). The development of a 256K DRAM marked a significant step for Samsung, as the R&D team in Silicon Valley was able to design a 256K DRAM circuit completely on its own. The knowledge and experiences became an important foundation for the firm to move onto the development of subsequent generations of DRAMs, such as 1M and 4M DRAMs. (Kim 1997)

Right after Samsung reached the final stage of developing the mass production system for 256K DRAMs in Korea, its R&D teams, both in Korea and Silicon Valley, started working on the development of a 1M DRAM. Its technological capability was such that the firm decided not to acquire technologies from external sources but to develop them in-house. Despite the significant technological changes from the 256K DRAM, Samsung's R&D teams were able to develop a 1M DRAM in 1986, reducing the gap with the Japanese pioneer from two years for the 256K DRAM to one year for the 1M DRAM. Samsung started its mass production of 1M DRAM also one year later than leading Japanese firms, including Hitachi and Toshiba. But this was not too late, as the firm still could enjoy the rapid rise in market demand. (Kim 1997)

Standards activities during catch-up

During the catch-up stage, Samsung acquired a substantial portion of its technical knowledge from equipment and raw-material suppliers. Technical training programs provided by these suppliers were an essential source of technical know-how for Samsung. These suppliers were the main source of technical specifications and standards, which became the main source for product development and mass production of relatively mature products.[25] Samsung's reliance on equipment and raw-material suppliers for standards and technical specification gradually decreased as the firm accumulated more in-house technological capability. The relationship between Samsung and its suppliers has also changed to a more co-working relationship than before. For earlier products, Samsung used the standard models purchased from suppliers. However, as its technological capability developed, Samsung used an increasing number of its own specifications for equipment for the suppliers to follow. As Samsung approached the stages of keep-up and forge-ahead, its relationship with equipment suppliers has become more collaborative. In fact, Samsung now co-develops some of the most advanced equipment with its suppliers (Choi 1996).[26]

The standards and technical specifications that Samsung acquired during its catch-up stage were based on relatively mature technologies. As its internal technological capability developed, it became more difficult for Samsung to acquire more advanced specifications. The forerunners at the time were unwilling to license their technologies to Samsung. This put tremendous pressure on Samsung to find other ways to acquire new specifications. This problem became serious, as Samsung entered its keep-up stage as a fast follower.

Keys to successful catch-up: quality, quality, and quality

Throughout the process of late standardization and technological catch-up, quality control and standardization is a key for latecomer firms to build a basic mechanism to move from one stage to another. Quality standards are important throughout the process, although they are particularly important for the early stages of technological catch-up. The types of standards that latecomers focus on are also different in different stages of technological development.

For Samsung Electronics, quality control and standards have long played a paramount role from the early years of its catch-up efforts. Since Samsung Electronics was founded in 1969, the company has used various tools and techniques for internal quality control and standardization. These include Total Quality Control (TQC), Total Process Management (TPM), Product Data Management (PDM), Enterprise Resource Management (ERM), Supply Chain Management (SCM), and Customer Relationship Management (CRM). Since 1999, Samsung has adopted and implemented Six Sigma as a core tool to improve its competitive position in the global market (Yun and Chua 2002).

Table 5.4 highlights the main standardization and quality control efforts at Samsung

Electronics in three different stages of late standardization and technological catch-up. During its catch-up stage, Samsung engaged in various aspects of standardization and quality control, some of which was developed by Samsung itself. For instance, right around 1986, Samsung adopted an internal standardization program called No Spec No Work (NSNW) policy, which is a quality standard and procedure for the manufacturing of all Samsung products. In essence, NSNW controls and audits the status of standard-observance of all manufacturing processes in the factories. Samsung has continued to implement this standard procedure even to this day in its domestic and overseas manufacturing operation (Stratton 2002).

Table 5.4: Standardization and Quality Management at Samsung Electronics

Types of Standards	Stages Catch-Up (up to 1989)	Keep-Up (1990-1998)	Forge-Ahead (1999-present)
Standardization	- No Spec No Work - Spec Audit	- Corporate Spec System - DOLPHINS - SQS - Global Spec Center	- Global Spec System - e-Spec
International Certification	- Ford -101	- ISO 9000 (Domestic) - BS 7750 (Domestic) - ISO 14000 (Domestic) - ISO 9000 (Cheonan)	- ISO9000 (SAS,SESS) - QS 9000 (S-LSI)
Quality System	- Customer Audit - IQA	- MBNQA Concept - EFQM Concept - Q-PLUS - Theme Audit	- INTEL SSQA - Q-COSTER
Customer Satisfaction	- Branch QA Set-Up - Joint Qual	- PCN/RMA - Self-Qual - RMA System - Area FAE	- Excalibur (SUN) - Best Supplier (Compaq)
Q-Engineering	- Statistical Process Control (SPC) - Design of Experiments (DOE)	- MSA - FMEA - CP - Statistical S/W - Q-College - Certification System - QDIS - SPC,Inter-lock	- Design for Manufacturability - Six Sigma

Source: Samsung's website: www.samsung.com

Another important aspect of standardization activities that Samsung has pursued since its early years of late standardization is international certification. One of the very first international certification for quality standards that Samsung received was Ford Q-101. Ford Q-101 is a status that is awarded to suppliers that successfully apply the Ford's Quality Operating System (QOS). Ford Q101 is an older version (1990) and the current standard/award is Q1 2002. QOS is an advanced approach to Total Quality Management (TQM), one of the techniques widely used in implementing the QS-9000 standard. QOS focuses on continuous improvement via strategic goals based on organizational missions, customer expectations and competitive benchmarks.

Samsung's standards activities during forge-ahead stage

From the early 1990s, Samsung has devoted significant effort into attaining the ISO 9000 standards series, one of the most important international standards for quality control and management. The ISO 9000 standards outline the policies and procedures for improving and controlling the various processes that are expected to result in improved business performance. Originally developed by the British Standards Institute, the ISO 9000 series has gained international and formal recognition. The standards are now maintained by the ISO and administered by accreditation and certification bodies.

Samsung obtained ISO9001 for the operation of its plants in Korea as early as June 1993, becoming one of the first semiconductor firms to acquire such certification (Table 5.5). All of Samsung's domestic and overseas semiconductor sites have acquired the ISO 9000 certification. The firm prides itself with the industry's most complete portfolio of zero-defect semiconductor components and TFT LCD screens. Samsung was also granted the revised version ISO9001: 2000 in 2001. Samsung's System LSI Business Unit acquired QS 9000 in 1999, and switched to the ISO 9001:2000 certified sites in 2002 while upgrading the quality management system. To date, Samsung has implemented a broad range of quality management system achievements, such as the ISO9000, TL9000 and the QS9000.[27]

Table 5.5: Samsung's Quality Certificate Milestones

Certification	Site		Registration Scope	Issued Date
ISO 9000	Domestic	Kiheung	Design and fabrication of memory, SYS-LSI semiconductor	Jun. 1993
		Kiheung, Chonan	Design and manufacture of LCD	Oct. 1995 Jan.1999
		Onyang	Assembly and test of memory, SYS-LSI semiconductor	Jun. 1993
	Overseas	SESS (China)	Assembly and test of semiconductor	Jun. 1999
		SAS (U.S.A)	Fabrication of memory semiconductor	Oct. 1999
QS 9000	Domestic	Kiheung, Hwasung, Onyang	Design, fabrication, assembly & test of memory, SYS-LSI semiconductor	Mar. 2002
TL9000	Domestic	Kiheung, Hwasung, Onyang, Chonan	Design, manufacture, assembly and test of memory, S-LSI, AMLCD	Oct. 2001

Source: Samsung's corporate website: www.samsung.com

Samsung acquired international certification for quality assurance and management for various industries. For instance, Samsung achieved TL9000, the international standard for the telecommunication industry, in October 2001, and QS9000, the international standard for the automobile industry, in March 2002. Its quality management system covers all stages, ranging from order receipt, development, production to shipment.

KEEP-UP: SAMSUNG AS FAST FOLLOWER (1985-1991)

For the subsequent generations of DRAM, Samsung had to compete directly against Japanese and U.S. leading firms. As the semiconductor market, especially for DRAM started to mature, the industry became more consolidated. This means there were few technology holders that could potentially become the provider of new technologies and designs for Samsung. The firm responded to this constraint by investing even more heavily in its R&D activities. The investment and efforts resulted in significant improvement of Samsung's knowledge base and technological capabilities. For instance, the number of local patents granted to Samsung rose from only 4 in 1980 to 1,413 in 1994. For technologies related to 4M DRAM alone, Samsung received as many as 56 patents (Kim 1997).

Samsung's technological efforts for 4M and 16M DRAMs are characterized by its ability to keep up with technology leaders in developing and mass producing the chips. The firm completed its design of 4M DRAM in 1988, only six months after the Japanese pioneer, Hitachi. With its accumulated knowledge in process technologies, Samsung was able to mass produce 4M DRAMs almost at the same time as the Japanese leaders. Similarly, Samsung was able to develop a 16M DRAM just three months after the world pioneer, Toshiba. In fact, with its superior process technologies, Samsung became the first firm to mass-produce 16M DRAMs in 1991 (Shin and Jang 2005).

Standards activities during keep-up

It was during this period when Samsung started paying attention to standardization activities in several standards forums.[28] One such forum was JEDEC, the Joint Electron

Device Engineering Council - Solid State Technology Association. Samsung first became a member of JEDEC in 1988, almost 15 years after it first entered the semiconductor industry.[29] It joined the standards organization when it had already emerged as a main player in the DRAM market. It was also the same year when Samsung entered the licensing agreements with Hitachi of Japan for 64K and 256K DRAM technologies (Choi 1996), a critical move that enabled Samsung to acquire necessary technologies for advanced semiconductor products.

In the late 1980s, it became obvious to Samsung executives that it was important and necessary for the company to join JEDEC. By that time, JEDEC was already the main forum for standardization of memory technologies. The executives recognized that memory products were the only "commodity" product left in the semiconductor industry for Samsung to enter and perform well. It thus seemed sensible for Samsung to join JEDEC. In addition, all major DRAM manufacturers at that time were JEDEC members. Particularly, leading Japanese manufacturers were the main actors in JEDEC in the 1980s and early 1990s. Samsung realized that for the firm to catch-up and keep-up with the new technologies, it would have to become part of this standards club.[30]

Another reason for Samsung's decision to join standardization activities at JEDEC was the pressure from its OEM customers. These OEM customers increasingly demanded that Samsung's memory chips would have to meet JEDEC standards. This made it necessary for Samsung to become part of JEDEC.

According to Gil Russell, who represented Samsung at the beginning of its JEDEC membership, the participation of Samsung during the first few years was limited to information gathering. Russell himself had been familiar with JEDEC, having worked for

NEC before joining Samsung. Hired by Samsung Semiconductor, Inc (SSI) to represent the firm at JEDEC, Russell would attend technical meetings to exchange ideas, while writing minutes and memos, having them translated and then sent directly to Samsung's R&D Division in Korea. We discuss the organizational structure of standards-related activities in Samsung in the next chapter.

One of the main motivations behind Samsung's decision to join JEDEC was the "curiosity" about what was going on in the industry. Before joining JEDEC, Samsung recognized that most leading firms in the industry, especially the Japanese, were the main actors in JEDEC. So the executives of the firm were curious about what was actually going on in the organization. By participating in standards activities, Samsung not only acquired the latest technical and market information in the industry, the firm could also meet with big vendors and buyers in the industry, who were also members of JEDEC. In effect, participating in standardization activities is a low cost way to meet vendors and customers.[31]

During its first few years in JEDEC, Samsung participated mostly as an observer. The number of committees and subcommittees in which Samsung participated were limited to a few. Samsung started to become influential in JEDEC around 1993-1994. The firm started to send more engineers and technical experts to participate in various JEDEC committees. As of January 2006, Samsung's engineers and executives are chairman or vice-chairman in four out of fifty-five committees/subcommittees.[32]

Quality standards and ramp-up capability

The use of quality standards and methods, such as Six Sigma, underscores Samsung's ability to ramp up its production to cope with shorter product- and technology-life cycles. The use of Six Sigma has enabled Samsung not only to improve and sustain the quality of the products but also increases the speed to market. The key to the speed to market is not only merely the improved manufacturing process itself, but includes the implementation of the standards and tools from the early stage of designing new products and/or processes.

Samsung utilizes the Design for Six Sigma (DFSS) methodology in designing new semiconductor products/processes to prevent anticipated problems and to collect feedback data for subsequent mass production. As increasing profits in the semiconductor industry are usually attributed to downsizing the chip sizes, continuous improvement and development of process technologies become a critical factor that affects competitiveness (Mathews and Cho 2000). A fast ramp-up capability is, in fact, one of the most important sources for Samsung's competitiveness (Shin and Jang 2005).

Samsung utilizes the Six-Sigma method extensively and successfully in process development for new semiconductor products. Unlike products that are made up of many component parts, such as refrigerators and TV, semiconductors are manufactured by putting together a set of photos, etches, and deposition processes onto a silicon wafer. This means the semiconductor manufacturing process relies greatly on a combination of individual procedure capabilities rather than the quality of the components (Kim et al. 2004). As part of the Six Sigma program for process development, Samsung prepares a process standard that engineers responsible for developing individual procedures have to follow. The implementation of DFSS allows Samsung to integrate its manufacturing processes with the development of new products. The successful integration results in the success in improving its ramp-up capability.

FORGE-AHEAD: SAMSUNG AS LEADER (1991-PRESENT)

Samsung became the industry leader in terms of market share for DRAMs in 1991 and for overall memory products in 1993. Within one decade since it entered the market, Samsung became one of the market leaders in the semiconductor industry. As of 2005, Samsung still retains its leadership position in the memory segment of the semiconductor industry. Samsung's global market share of DRAM has been more than 30% since 1998. In 2002, it became the world number one in LCD IC market and the world number two in the overall semiconductor market only behind Intel. Furthermore, in 2003, it became the market leader for Flash memory.[33] This sustained industry leadership attributes greatly to do the company's technology and standards strategies and capabilities.

Soon after it became the market leader in DRAM, Samsung became a world technology leader in that business in 1992, when it became the first to have successfully developed a 64K DRAM. Since then, Samsung has sustained its technological leadership, being the first in the world to develop and mass produce the four subsequent generations of DRAMs. These include the development of 4M DRAM in September 1992, 256M DRAM in August 1994, 1G DRAM in November 1996, and 4G DRAM in February 2001.[34]

Samsung has remained the leader in developing high-end DRAMs. It introduced the 64M synchronous DRAM (SDRAM) in 1996, which was four times faster than the normal 64M DRAM. It also introduced the 256M SDRAM in 1999. Other DRAM manufacturers resisted the introduction of the Rambus DRAM, fearing that Intel was imposing its standards on DRAM manufacturers. However, because of its resources and bold strategy, Samsung developed both the Rambus DRAM and DDR Double-Data-Rate DRAM (DDR DRAM).

Samsung proposed both standards separately to standards forums (Shin and Jang 2005).

Samsung's technological leadership is not limited to DRAMs, but includes several other semiconductor products. For instance, the company was the first to develop an ADSL chipset (2000), 533MHz Mobile CPU/1.3M Pixel CIS (2003), and 8Gb NAND Flash / 80nm 2Gb DDR2 (2004). More recently in September 2005, the company announced its development of the world's first 10-chip multi-chip package (MCP) and world's highest density NAND flash, a 16Gigabit (Gb) NAND memory device.[35] These accomplishments confirm that Samsung has developed beyond the stages of catch-up and keep-up and become one of the world technological leaders in the semiconductor industry, particularly in the memory segment.

Samsung as standards leader (1996-present)

Technological leadership alone does not guarantee that firms can sustain first-mover advantages and forge ahead of the competitors. Technological leadership needs to be strengthened and sustained by standards leadership. Standards leadership is another important aspect of Samsung's technological success, which is more recent and less well documented.

As a standards leader, Samsung's participation in standardization activities is increasingly proactive. Samsung is now a member in several major international semiconductor standards organizations, including SEMI, JEDEC, and SEMATECH. Our discussion in this section focuses on Samsung's participation in JEDEC. The main reason is that JEDEC is the key forum in which standards for memory products have been developed, and that memories, especially DRAM, are the products in which Samsung has made the most significant progress both in terms of market share and technological leadership.

Standards leadership is manifested through a firm's influence in standards development. One indication of Samsung's standards leadership is that its proprietary technologies have been adopted as core technologies of new semiconductor standards. Another indication is that Samsung's employees are assuming leadership positions in standards forums. Such positions include chairing technical committees and membership in the boards of directors.

Samsung is certainly perceived now as one of the top leaders of the semiconductor industry. We interviewed a few people at JEDEX, one of the main meetings of JEDEC, who represented other firms in the semiconductor industry. Representatives from not only technology leaders, such as IBM and Intel, but also from fast-following firms, such as Hynix from Korea and Via from Taiwan, all consider Samsung as a leader and that they have to "listen to" Samsung. In addition, in several semiconductor conferences, especially in the memory area, Samsung executives often speak as the keynote speakers. This indicates the recognition of Samsung by other firms in the industry.

Indication of standards leadership (1): Influence on standardization outcome

Samsung's leadership in semiconductor standardization is indicated by its efforts in influencing the choices of technologies to be adopted as JEDEC standards. Our interviewees from Samsung and other JEDEC member companies all suggested that Samsung's leadership became evident with the standardization of Double-Data-Rate Synchronous Dynamic Random Access Memory (DDR-SDRAM) technologies. Samsung proposed DDR to JEDEC in December 1996. At that time, there were already a few technologies that could become the industry standards for advanced synchronous memory products. Yet, Samsung's engineers believed that their technologies yielded better performance than other technologies that had been proposed. They continued to present and persuade other members to consider Samsung's technologies. Samsung finally demonstrated its leadership in July 1997. Its bi-directional DDR SDRAM technology was officially considered by the board of directors of JEDEC and the company demonstrated the world's first DDR silicon in a 64MB device.[36]

Simply put, Samsung led the way for standardizing DDR SDRAMs. It proposed, endorsed, and adopted new DDR standards that it developed jointly with other firms in JEDEC. Samsung became an early leader supplying to the DDR market in the second half of 1999. It has since become one of the strong leaders of standardization of synchronous memory products. Towards the end of the 1990s, semiconductor firms were competing for an advanced version of synchronous memory chips. The market was divided between the following three competing standards: namely, (1) RDRAM - Direct RAM developed by Rambus and supported by Intel; (2) SLDRAM – championed by SLDRAM Inc., a consortium led by Siemens (in which Samsung was also part of); and (3) DDR-SDRAM championed by a consortium led by Samsung. SLDRAM lost the standards game and changed its focus to DDR 2, an advanced version of DDR. Meanwhile, Rambus became involved in a prolonged series of lawsuits against other manufacturers that pursued the DDR approach.[37]

With the demise of SLDRAM, Samsung pursued both the RD-DRAM and DDR-DRAM approaches for its product development and production. As Rambus started to claim its patents were included in the DDR technologies, Samsung started to license. The firm developed the 64M RDRAM in 1998 and began mass producing 64M, 72M, and 144M RDRAMs from 1999. Nonetheless, Samsung focused its standardization efforts on DDR technologies. It finally introduced the 1G DDR SDRAM in 1999.[38]

Samsung started 64MB DDR production in mid-1998. The company started the world's first mass production of DDR266 in 2000, and started mass production of DDR333 SDRAM in 128MB, 256MB, 512MB densities in 2001.[39] As of 2006, Samsung has the highest number of industry-validated memory modules available. This broad technological portfolio is strengthened by its active involvement and leadership in external standards activities.

Indication of standards leadership (2): leadership positions in standards forums

Samsung's active involvement and strong influence in the area of semiconductor standards are also manifested through its engineers and executives becoming influential in JEDEC. In fact, some of its personnel are now among the leaders of JEDEC. For instance, Mian Quddus, the Marketing Vice President at Samsung Semiconductor in San Jose, CA, was elected Chairman of JEDEC's Board of Directors for a two-year term beginning in January 2004. Prior to his election, Quddus served on the JEDEC Board of Directors for 10 years.[40]

Similarly, Dr. Dong-Yang Lee, a senior engineer in Samsung Electronics' memory group in Korea, was honored by JEDEC with the associations' Award of Excellence. The award recognizes Dr. Lee's leadership in developing and establishing standards for DDR and DDR2 SDRAM technology. Based at Samsung's lab in Korea, he is the lead designer of the world's first DDR SDRAM memory.

Dr. D.Y. Lee was a key figure in the DDR SDRAM technology development, heading JEDEC's DRAM specification committee and playing a leading role in multiple task groups. He is the author of the JEDEC JESD79-2 DDR2 SDRAM specification and several other JEDEC memory standards since 1996. Earlier in 2002, he was also a recipient of JEDEC's

Technical Recognition Award for his contribution to developing and standardizing DDR SDRAM technology. Dr. D.Y. Lee's award marks only the third time that the Award of Excellence has been presented to a JEDEC member since it was established in 1958. It is awarded by JEDEC's Board of Directors to honor exceptional contributions to technology standardization that are critical to the success of the global electronics industry benefiting both suppliers and end users.[41]

The path for Samsung's emergence as a standards leader at JEDEC was not a road full of roses. According to an interview with Dr. D.Y. Lee in April 2004, it took Samsung, and Dr. Lee personally, a few years before their technologies could be considered and accepted as part of JEDEC standards. When Dr. Lee first presented his ideas and research results for the DDR technologies in 1996, he received very little attention among JEDEC members. Over the span of three years, Dr. Lee had presented his ideas five times before the JEDEC Board of Directors were willing to put the draft standard up for voting.

It was not until July 1999 when the DDR SDRAM standard was finally approved by the JEDEC Board of Directors and was published as a JEDEC standard in June 2000. According to Managing Director Soo-In Cho of Samsung's DRAM Design Laboratory, by that time, Samsung had already started its production of DDR SDRAM, Rambus DRAM and PC133 SDRAM, and was the first manufacturer to have both developed and mass-produced the products.[42] Samsung's contribution and leadership has continued in the effort to develop new standards for DDR2 and DDR3, the subsequent and advanced versions of DDR-SDRAM.

In sum, Samsung Electronics has managed to move beyond being a standards follower to become a standards leader in the semiconductor industry. The firm first became a market leader of DRAM in 1991, then became a technology leader of 1G DRAM in 1996, and finally became a standards leader of DDR-SDRAM in 1997. Its standards leadership is demonstrated through its influence on standardization outcome, which often includes Samsung's proprietary technologies, as well as its employees assuming leadership positions in standards forums.

Standards leadership for sustaining competitive advantage

Standards leadership contributes significantly to Samsung's competitive advantage. One important channel is through product development. Our interviewees, both from Samsung and other firms in JEDEC, suggest that there is indeed a strong relationship between leadership in standards development and product development.

Samsung was the first to produce DDR-DRAMs and DDR2-DRAMs in 1998 and 2001 respectively. As a result of its leadership in DDR2 standardization, Samsung has the broadest DDR2 product line in 2005, and has shipped more DDR2 products than any other manufacturer. Samsung maintains its leadership in the DDR market, holding more than 50 percent market share of DDR333 SDRAM. The company expects to continue its leadership in DDR memory by being first-to-market with leading-edge devices in a wide range of configurations and densities. Its standards leadership is indeed closely related to its continuing market leadership.

More recently, in February 2005, Samsung announced its 512Mb DDR3 prototype, which would enable ultra-fast computer application processing with reduced power consumption. According to IDC, a semiconductor market research firm, the first DDR3 DRAMs are predicted to be sold in 2006 and the chip will represent 65% of the entire DRAM market in

2009.[43] Samsung's leadership in standardization indicates high possibility that the firm will also become a leader in the future DDR3 market.

Standards could be developed in advance long before the products based on such standards are developed, produced, and sold in the market. For instance, in 2002, JEDEC began drafting the first DDR3 industry standard even though DDR2 for PC and server main memory had yet to come to market. A final JEDEC standard for DDR3 was completed by the end of 2005, with sampling starting a year later and production in 2007 (Robertson 2002).

A long and winding road to standards leadership

It takes time for any firm, let alone a late standardizer, to become influential in a standards forum, even with superior technologies. According to Gil Russell, a former Samsung's representative at JEDEC, it normally takes at least six months for a newcomer to learn about what is going on in JEDEC. Then it takes another year to become effective in participating in standardization activities. One needs at least two years in order to become proactive and influential in standards development.

The reason behind such a long process has to do with non-technical factors that affect standardization processes. In fact, technical excellence is not the only factor that makes a technology an industry standard. Participation in standards development process involves more than formal meetings of technical committees. Much negotiation and discussion occurs outside the formal occasions, often in the hallways. As many of our interviewees indicate, "hallway politics" is an important factor in determining technological standardization. Technical superiority could be a determining factor as to which technologies are adopted as standards. However, it is often difficult to determine which technologies are absolutely better than others, partly because there are many criteria by which technical superiority can be measured. It is thus often left to negotiation and politics between parties involved.

As several interviewees at JEDEC have told us, politics within standards organizations makes it critical for participating firms to make a continuous and strong presence in standardization activities. Many firms send the same people who already have extensive knowledge about the standards forums. In fact, they often hire away standards experts from other firms that participate in the same forums. As Gil Russell puts it, "the company names [on the name tags] may change but the faces don't". In other words, many standards experts represent different companies in the same standards forums throughout their careers.

Quality management and standardization for R&D

During the stages of technological catch-up and keep-up, Samsung focused its quality control efforts on manufacturing processes. Several of the quality standards and certification mentioned above, including ISO9000, QS9000, and TL9000, are implemented primarily to improve production processes. However, as firms attempt to develop R&D capabilities, other standards become useful. One of those is Six Sigma. Pioneered by Motorola in the mid-1980s, Six Sigma is a quality management tool used to improve operational performance by identifying and correcting defects in processes and products. Six Sigma can be implemented on a wide range of new functions and processes, including transactional activities.

Samsung started implementing Six Sigma in 1999. Samsung's Advanced Business Planning and Strategy Department was convinced that Six Sigma would be a good process tool for its development and manufacturing of products (Stratton 2002). The company started to integrate Six Sigma into its entire business process, namely, research and development, procurement, manufacturing, logistics, marketing, sales, and services. The focus of Samsung's Six-Sigma implementation was on products as well as human resources development. Samsung subcontracted the task of training for management and other employees responsible for deployment planning to Juran Institute, a Connecticut-based consulting firm specialized in quality control and management. Every employee in Samsung is required to take the Six Sigma training. As an indication of how seriously Samsung invests in Six Sigma, the firm completed 3,290 Six Sigma projects in 2001 and 2002, and another 4,720 projects in 2002. After only three years of implementation, the number of Samsung employees with Six-Sigma certification, i.e., Master Black Belt (MBB), Black Belt (BB), and Green Belt (GB), was more than 15,000 (Yun and Chua 2002), that is, approximately one of every three employees in Samsung. Its corporate goal is to have 100 MBBs, 3,000 BBs, and 30,000 GBs by the end of 2004.

The implementation of Six Sigma has contributed significantly to Samsung's competitive advantage. According to Yun and Chua (2002), Six Sigma projects implemented at Samsung Electronics played a major role in the firm's recent growth, contributing to an average of 50 percent reduction in product defects between 1999 and 2001. According to Keith Kim, Samsung's senior vice president for Corporate Quality, quality has improved about 20-30 percent since Samsung started Six-Sigma training for its employees.

OTHER LATE STANDARDIZERS IN SEMICONDUCTOR

We have selected Samsung Electronics as the main case study of our research in the semiconductor industry because of its outstanding success in the past few decades. We have also selected a couple of other late standardizers from Korea and Thailand as our "shadow" case studies. The objective is to generalize the findings from the Samsung case. Hynix Semiconductor in South Korea is another late standardizer that has attempted to move beyond technological catch-up and become a technology and standards leader. We discuss the Hynix case in detail in this section.

HYNIX SEMICONDUCTOR

Based in Ichon, South Korea, Hynix Semiconductor is a world's top-tier memory semiconductor supplier offering Dynamic Random Access Memory chips (DRAMs), Static Random Access Memory chips (SRAMs), and Flash memory chips to a wide range of established, international customers. Hynix Semiconductor was founded in 1983 as Hyundai Electronics Industries as part of the Hyundai Group. In the 1980s and 1990s, Hynix was mainly focusing on manufacturing and marketing DRAM, and then later SDRAM. The company was hit hard by the Asian financial crisis in the late 1990s, having to restructure its businesses and corporate structure. The company merged with LG Semiconductor in 1999, and changed the company name to Hynix Semiconductor in 2001.

Hynix's technological development

Hynix's technological development is similarly impressive as that of Samsung. It has significantly improved its technological capability in the past two decades. Hynix's process of technological capability has also developed through three distinct stages of catch-up, keep-up, and forge-ahead. Starting from relying on mature technologies acquired from foreign sources, the company continuously improved its manufacturing capability. The company invested heavily in enhancing its in-house innovation capability so as to become a fast follower of advanced technologies. Hynix implemented several strategies for technological development and acquisition. The company's Semiconductor Research Institute was established as early as 1986. The company also joined the research consortium established by the Korean government aiming at developing domestic DRAM technologies. Before the financial crisis started in 1997, Hynix had acquired equity stakes in several firms in the United States as part of its strategy to acquire advanced technologies (Kim 1997).

Table 5.6: Technological Milestones of Hynix

Year	Milestones
2004	Developed the industry's first ultra-high speed DDR SDRAM 550MHz
2004	Developed NAND flash memory
2003	Developed the world's first DRAM 1Gb DDR2
2003	Developed the world's first ultra-high speed DDR500
2003	Introduced the world's first commercially applicable mega-level FeRAM
2002	Developed 0.10-micron 512MB DDR
2002	Developed the world's first high-density, wide-bandwidth 256MB DDR
2002	Developed the world's first 256MB SDR SDRAM for high-end consumer application
2002	Developed 1G DDR DRAM module
2001	Developed the world's first 128Mb DDR SDRAM for graphics
2001	Acquired customer validation of DDR 333 from Taiwan's SiS
1998	Developed 64M DDR synchronous DRAM
1997	Developed the world's first 1G synchronous DRAM
1995	Developed the world's first 256M SDRAM
1993	Acquired ISO 9001 certification on semiconductor category
1992	Developed 64M DRAM
1991	Developed 16Mb DRAM
1989	Completed construction of FAB III
1989	Developed 4M DRAM
1988	Developed 1M DRAM
1986	Established Semiconductor Research Institute
1985	Started mass production of 256K DRAM
1984	Completed construction of FAB II-A
1983	Founded Hyundai Electronics Industries Co., Ltd.

Source: Adapted from Hynix website: www.hynix.com

Hynix's manufacturing and innovation capabilities improved rapidly in the early 1990s. In 1994, the company became one of the first companies to have mass-produced 16M DRAMs.[44] By the end of the 1990s, Hynix was able to develop several DRAM technologies for the first time in the world (Table 5.6). In some technical areas, Hynix not only has caught up and kept up with technology forerunners in the United States and Japan, as well as Samsung, but has also forged ahead. These technological achievements include, among others, the world's first

1G synchronous DRAM in 1997, 128Mb DDR SDRAM for graphics in 2001, and DRAM 1Gb DDR2 in 2003.

Hynix's late standardization

Hynix has increasingly become more active in external standardization activities.[45] The firm participates in various committees and conferences organized by JEDEC and other standards organizations in the semiconductor industry. Its participation and contribution in JEDEC, however, is not as extensive as that of Samsung. The number of delegates to technical committees is smaller; about seven Hynix engineers are involved in JEDEC standards activities. Currently, there are no Hynix employees on the JEDEC Board of Directors. Judging from Hynix's current participation and contribution to external standardization activities, we would argue that the company is not yet a standards leader, even though it has become a technology leader in several technical areas.

According to our interviews with Hynix engineers, the company's limited contribution to JEDEC standardization is due to its current emphasis on process technologies, rather than on product design. Hynix has achieved a high level of manufacturing capability, which directly affects the yield rates and the resulting profits. The recent financial trouble was another problem that had forced the R&D teams to focus on relatively short-term projects that were aimed to increase its revenues and profit. Standards-related projects tend to be long-term, and require substantial amount of resources.

Nonetheless, our interviewees expect that Hynix will increase its effort in standardization activities, partly because the company has recovered from the financial problem and earned high profits in the past couple of years. They also acknowledge the various benefits of being part of the standards clubs. These benefits include the glimpse into competitors' technology and product development plans, the knowledge about emerging standards, which will help shape its internal product and production design, and the influence that the company can exert on standardization outcomes. As process technologies are considered to be Hynix's source of competitive advantage, Hynix's engineers who participate in external standards activities often hold meetings with process engineers to maximize the benefits from their participating in standardization forums.

In fact, Hynix now considers external standardization in JEDEC as an important element of its technological and business strategies. In November 2005, Hynix announced the availability of the industry's first JEDEC-standard 8GB DDR2 Registered Dual in-line Memory Modules (R-DIMMs). In developing such a product, Hynix benefited greatly from its proprietary multi-die stacking technology. Hynix's development of the JEDEC-standard 8GB DDR2 R-DIMM demonstrates the company's technical expertise and strong competitiveness built upon its manufacturing capability.

HANA SEMICONDUCTOR

Hana Semiconductor is a subsidiary of Hana Microelectronics Public Co.,Ltd., an Electronic Manufacturing Service (EMS) producers and one of Thailand's leading high-tech companies. Headquartered in Bangkok, Hana is a subcontractor company with several multinational and leading OEM companies in the electronics industry, such as Texas Instruments. Hana's semiconductor products include customer-specific packages, such as assembly of Light Emitting Diodes (LED), optoelectronic packages (OPTO), and hybrid devices on a captive line basis. [46]

Our case study of Hana Microelectronics of Thailand reveals that the company's external standards effort is very limited compared to those of Samsung and Hynix. The company is participating in only a few standards committee, including the JEDEC JC11 committee on packaging outline and the JC15.1 committee on thermal characterization. Its participation in standards activities suggests that the company is trying to become fast followers of new technologies and standards. Its focus, however, is primarily on internal quality management standards. Its external standards activity aims primarily at acquiring knowledge that will help improve its manufacturing processes.

Hana's LED and OPTO operations have followed the JEDEC-standard quality criteria. Hana has also implemented quality standards and procedures, including SPC, TQM and ISO9001/2000, ISO9002, QS9000, ISO14001 and TS16949. We would therefore argue that Hana is a late standardizer in the catch-up stage, which is trying to become a fast follower. Its standards activities are still limited to quality standardization and management.

CONCLUDING REMARKS

We have shown in the chapter how late standardizers in the semiconductor industry have engaged in standards activities both internally and externally. Our case study of Samsung Electronics shows that standards and related activities are learning and linking apparatus for a latecomer firm to leverage their limited resources and capabilities so that it can move up the ladder of competitive advantage. Samsung's emergence as a leader in the industry was first manifested through its market share, then through its technological breakthrough, finally through its influence on technical standardization. Although the focus on quality standards and procedures have always been important since the early years, as Samsung moves closer to the world technological frontier, external standardization activities become a key factor in determining Samsung's competitiveness. Through standards activities, Samsung has linked itself with technological leaders and other firms in industry, so that the firm can leverage its limited resources and capabilities. Also through standards and standards activities, Samsung learned about new technological and business trends in the industry. Samsung's history of engagement in standards activities corresponds to the staged model of late standardization and technological catch-up that we have proposed earlier. Samsung is now clearly a standards leader in the semiconductor industry, as indicated by its active participation in standards forums, its influence of standardization directions and outcome, and its personnel in leadership positions in standards forums. We now turn our attention to the case studies of late standardizers in the mobile telecommunication industry.

CHAPTER SIX

CASE STUDIES OF LATE STANDARDIZERS IN MOBILE TELECOM

MOBILE COMMUNICATION TECHNOLOGIES AND SERVICES ■ LATE STANDARDIZATION OF KOREAN FIRMS ■ ORGANIZATIONAL STRUCTURE FOR STANDARDS ■ STANDARDS AND INTELLECTUAL PROPERTY ■ THAI LATE STANDARDIZERS IN MOBILE TELECOM ■ CONCLUDING REMARKS

Mobile communication is another industry in which late standardizers have emerged as standards leaders. A few Korean late standardizers, notably Samsung Electronics, LG Electronics, and KT, have been able to lead standardization activities for certain mobile telecom technologies both domestically and internationally.[47] In this chapter, we discuss the late-standardization process of these firms. We first give an overview of the different generations of standards and technologies for wireless telecommunication. This overview is essential to the subsequent analysis of the developmental phases of late standardizers in mobile communication services in Korea. Then, we discuss the case studies of Samsung Electronics, LG Electronics, and KT. We pay attention to their general standards activities during the course of technological development, the organizational structures for standards activities, and the use of standards as part of the strategies and policies for protecting and utilizing intellectual property.

MOBILE COMMUNICATION TECHNOLOGIES AND SERVICES

In this section, we give an overview of mobile communications technologies and services in general and in Korea in particular. This serves as the background the following analysis of Korean late standardizers in the mobile telecom sector. We first focus on the generations of wireless communication technologies and standards. Then, we discuss the development of mobile technologies and services in Korea.

GENERATIONS OF WIRELESS COMMUNICATION TECHNOLOGIES

The mobile communication services took shape as an industry around the early 1970s. In the past four decades, the industry has experienced at least four main generations of technological shifts in terms of core technologies and standards that underlie the services and business (Funk 2002). As summarized in Table 6.1, several technologies were competing to become the industry standards for each generation of mobile communications.

Before cellular technologies were introduced as the technologies for wireless communication, mobile telephones in the 1970s were mostly installed in vehicles, although briefcase models were available in the market. This pre-cellular mobile telephony is referred to as 0G (0-Generation) technology. 0.5G technologies are basically 0G technologies with improved features. The cellular concept was later introduced in 1G standards, including the Nordic Mobile Telephone (NMT) standard, the Advanced Mobile Phone System (AMPS) standard, and the Total Access Communication System (TAGS) standard. These 1G technologies made possible mobile communication possible at the large scale.

Table 6.1: Evolution of Main Technologies and Standards of Mobile Communication

Generation	Main Standards		Generation	Main Standards	
0G	PTT	Push to talk	2G (cont.)	cdmaOne	Code Division Multiple Access Technology
	MTS	Mobile Telephone System		PDC	Personal Digital Cellular
	IMTS	Improved Mobile Telephone Service		TDMA	Time Division Multiple Access
	AMTS	Advanced Mobile Telephone System	2.5G	GPRS	General Packet Radio Service
0.5G	Autotel/ PALM	Public Automated Land Mobile		WiDEN	Wideband Integrated Dispatch Enhanced Network
	ARP	Autoradiopuhelin, Car Radio Phone	2.75G	CDMA2000 1xRTT	A TIA standard (IS-2000) evolving from cdmaOne
	HCMTS	High Capacity Mobile Telephone System		EDGE	Enhanced Data rates for GSM Evolution
1G	NMT	Nordic Mobile Telephone	3G	W-CDMA	Wideband Code Division Multiple Access
	AMPS	Advanced Mobile Phone System		UMTS	Universal Mobile Telecommunications System
	TAGS	Total Access Communication System		FOMA	Freedom of Mobile Multimedia Access
	JTAGS	Japan Total Access Communication System		CDMA2000 1xEV	CDMA2000 with 1xEV technology
2G	GSM	Global System for Mobile Communications		TD-SCDMA	Time Division Synchronous Code Division Multiple Access
	iDEN	Integrated Digital Enhanced Network	3.5G	HSDPA	High-Speed Downlink Packet Access
	D-AMPS	Digital Advanced Mobile Phone System based on TDMA	3.75G	HSUPA	High-Speed Uplink Packet Access

Source: Adapted from Network Dictionary at www.networkdictionary.com (accessed January 28, 2006); Funk (2002)

The basic concept of cellular phones began in 1947 when researchers looked at crude car phones and realized that by using small cells, i.e., ranges of service areas, with frequency reuse could substantially increase the traffic capacity of mobile phones. Yet, the technology to do it was nonexistent back then. By 1977, AT&T Bell Labs built and tested a prototype cellular phone system. In 1978, public trials of the new cellular phone system started in Chicago with over 2000 trial customers. In 1979, the first commercial cellular phone system began operation in Tokyo. In 1981, Motorola and American Radio Phone started a second U.S. cellular radio-phone system test in the Washington/Baltimore area. By 1982, the U.S. Federal Communications Commission finally authorized commercial cellular phone services. In 1983, the firm Ameritech offered for the first time in the United States a commercial service of AMPS (Advanced Mobile Phone Service) in Chicago.[48]

While 1G standards were based on analog technologies, second-generation (2G) mobile standards were developed with digital technologies, which resulted in significant improvement in terms of quality and reliability of the wireless communication. The main 2G standards are Global System for Mobile Communications (GSM), Time Division Multiple Access (TDMA) and Code Division Multiple Access technology (cdmaOne). 2G technologies were primarily developed for voice communications, although some of the 2G standards, such as GSM, allow for data transmission in the form of short-message services (SMS). 2.5G and 2.75G standards are based 2G standards with improved features and larger capability to transfer more data communications.

As 3G technologies, such as W-CDMA and CDMA2000-1xRTT, were developed and increasingly became industry standards, data communication became the main focus. There is now an increasing convergence between data and voice communications, with more and more voice, data and multi-media communications being carried out over broadband wireless networks. The industry is now working on the 4G technologies and standards.

Development of mobile communication services in Korea

We categorize the development of mobile communication services in South Korea according to the generations of main wireless technologies. As summarized in Table 6.2, Korean late standardizers were latecomers to the 0Ga and 1G standards until around the late 1980s. They managed to keep up with the technological change and became fast followers during the era of 2G standards. Since the late 1990s, the Korean late standardizers have become the forerunners in the 3G standards.

Table 6.2: Timeline for Mobile Service Operations in South Korea

Standards	First Generation (1G) (Analog Technologies)	Second Generation (2G) (Digital Technologies)		Third Generation (3G) (Broadband Digital Technologies)	
Service Provider	AMPS	IS-95a CDMA	IS-95a CDMA	CDMA 2000 1x	CDMA 2000 1x EVDO
SKT	7/1988	1/1996 (world first)	8/1997 (world first)	10/2000 (world first)	11/2002
KTF	4/1984	10/1997	7/1999	5/2001	5/2002 (world first)
LGT	n.a.	10/1997	n.a.	5/2001	n.a.

Source: Yoo et al. (2005)

Catch-up as latecomer: 0G and 1G mobile standards (1984-1989)

Mobile communication services were offered for the first time in South Korea in 1984. Korea Mobile Telecommunications Service (KMTS), a subsidiary of state-owned Korea Electricity and Telecommunication Corporation (KET, later changed to Korea Telecom then KT), offered primarily car-phone services in the Seoul area, which were later expanded to cover the whole country in 1991. (Lee and Han 2002)

In establishing the domestic mobile communication infrastructure, KMTS relied on foreign venders for the 1G mobile technologies. Because KMTS chose the AMPS standard, the de facto U.S. standard, for the Korean market, the service provider imported most of the equipment from Motorola and AT&T (Yoo et al. 2005). The heavy reliance on foreign technologies was also evident in the handset industry. Korean firms mostly imported handsets or most of the components from foreign partners and sold them in the domestic market. For instance, Samsung Semiconductor imported handsets or the components from Toshiba, Kumsung Electricity from NEC, Daeyoung Electronics from Motorola, and Hyundai Electronics from Novatel. Motorola dominated the Korean market throughout the period of the first-generation technology. However, its dominance started to decrease around 1995, when the industry began shifting to the CDMA standard, which Korea adopted for its 2G services (Lee and Han 2002).

During the first generation of mobile services in Korea, domestic late standardizers played a limited role. The market was dominated by foreign firms, such as Motorola. The Korean state played a critical role in establishing KMTS as the service provider, which eventually became SK Telecom, the largest mobile carrier in Korea. In the early 1980s, the Korean government identified telecommunications as one of the nation's strategic industries (Lee et al. 1994).[49] The Korean state played a critical role in nurturing the domestic market not only by establishing the domestic provider, but also by restricting the monopoly power of foreign firms (Lee and Han 2002). In addition, the Korean state also controlled the direction of industry development by selecting specific standards for the domestic market. We will discuss this issue in detail in Chapter Seven.

The prominent roles played by the state and foreign firms do not mean that this period was not important for the development of late standardizers. In fact, this period was very important as domestic firms were building up their technological capability. Without much technology transfer from foreign firms, handset manufacturers, such as Samsung and LG, together with the state, started manufacturing mobile handsets locally, even though their market shares remained low and most of the components were imported from overseas (Lee and Han 2002).

Technology transfer from research institutes, such as the Electronics and Telecommunications Research Institute (ETRI), was an important factor that laid a foundation for latecomer firms' subsequent technological development. For instance, in the late 1980s, the Ministry of Communication and the Telecommunication Development Task Force (TDTF) transferred the TDX-1 technology from ETRI to four domestic manufacturers, including LG Semiconductor, Samsung Semiconductor and Telecommunication, Daewoo Telecommunication, and Oriental Electronics and Telecommunication. The TDTF research consortium became successful in improving technological capabilities of these latecomer firms in the field of telecommunication, particularly in digital switching systems (Lee et al. 1994).

Keep-up as fast follower: 2G mobile standards (1989-1996)

The second generation of mobile services was when the Korean late-comers started to emerge as important players, first in the domestic market, then the global market. The emergence of these latecomers was driven mainly by the efforts of the Korean government and ETRI. As the domestic mobile telecom industry was seeking ways to reduce its dependence on foreign technologies for the first-generation mobile services, the MIC launched the Digital Mobile Telecommunication System Project 1989, which aimed to develop a total mobile service system for Korea, including base systems, switching stations, and handsets (Lee and Han 2002). Although the original project plan was to develop a new system based on the IS-54 TDMA standard, the negotiations with the developers of the standard, including AT&T, Motorola, and Northern Telecom, were without success. The intellectual-property holders of the technologies contained in the TDMA-based GSM standards were reluctant to transfer technologies to the Korean agencies and companies. The Korean government and ETRI were thus forced to look for alternative standards.

After some extensive research, an ETRI research team found out that a U.S. start-up company named Qualcomm had the core technologies for the Code Division Multiple Access (CDMA) standard, which could be adopted to develop the new system for Korea. The CDMA standard had shown greater efficiency in frequency utilization and higher quality and security in voice transmission than other systems (Lee and Lim 2001).

The collaboration between Qualcomm, ETRI, and Korean latecomer firms thus appeared to be a win-win solution for the parties involved, as their resources and capabilities complement one another. While Qualcomm had the core CDMA technologies, ETRI had a strong competence in switching systems. Korean latecomer firms, on the other hand, had built up manufacturing capabilities for mass production from their early experiences during the first-generation technologies. The CDMA collaboration project started in 1991, with the agreement that ETRI would develop the switching stations and base stations, the handsets, as well as the technological standards for Korea. Under the agreement, Qualcomm would develop the whole CDMA system, the base systems, and the basic design for handsets (Lee and Lim 2001; Lee and Han 2002).

In 1993, the Korean government designated CDMA as the only standard for the second-generation mobile communication services in Korea. Three years after that, in January 1996, SKT became the first service provider in the world to offer commercial CDMA cellular services in the Korean cities of Inchon and Buchon.[50] By this time, the Korean late standardizers had already established themselves as the global leaders in CDMA mobile communication services. They became the world leader, not only in terms of technological development but also in terms of standards development. By adopting the CDMA standards earlier than other leading firms and countries, the Korean late standardizers, as well as the Korean government and research institutes, were able to quickly improve their production and design capabilities.

Forge-ahead as leader: 2.5G and 3G mobile standards (1997-present)

Once the Korean late standardizers have established their foothold as leaders of CDMA-based handsets and network equipment, their successful technological efforts continue in the 2.5h and 3rd generation of mobile technologies. In October 2000, SKT started to offer the broadband mobile services based on CDMA 2000 1x standards for the first time in the world. KTF and LGT also started their 2.5G services half a year later. However, in order to cope with large volume of data transmission, the mobile industry started to experiment with 3G standards and technologies. After a long discussion and negotiation, the International Telecommunication Union (ITU) designated a set of technologies called IMT-2000 to be the global standard for the third-generation mobile communication. The two standards that Korea has adopted, that is, W-CDMA and CDMA2000, are both included in the IMT-2000 standard. While CDMA2000 evolved from the 2G CDMA technology that the Korean consortium developed with Qualcomm, W-CDMA evolved from the GSM standard.

LATE STANDARDIZATION OF KOREAN FIRMS

In the following section, we discuss in detail the late-standardization process of three case studies: two handset and equipment manufacturers, Samsung Electronics and LG Electronics, and one service provider, KT Corporation.

SAMSUNG ELECTRONICS

In addition to the semiconductor industry, Samsung Electronics has become a global player as well in the mobile telecom industry. Since the establishment of Samsung Semiconductor and Telecommunication in 1977 (later merged into Samsung Electronics), the firm has transformed itself from being a low-cost manufacturer of simple electronic and communication products, such as black-and-white televisions, into a technology and standards leader of the global telecom industry. Samsung is now a market leader in the CDMA mobile phone business, with the market share of 28 percent for 2004. It is ranked third overall for the mobile phone business, behind Nokia and Motorola (Table 6.3).

Table 6.3: Top Vendors in Worldwide Mobile Phone Shipments and Market Share

Rank	Vendor	Shipments (in millions)		Market Share (%)		Growth (%)
		3Q2005	3Q2004	3Q2005	3Q2004	
1	Nokia	66.6	51.4	32.0	29.4	29.6
2	Motorola	38.7	23.3	18.6	13.3	66.1
3	Samsung	26.8	22.7	12.9	13.0	18.1
4	LG	15.5	11.8	7.4	6.7	31.4
5	Sony Ericsson	13.8	10.7	6.6	6.1	29.0
6~	Others	46.9	55.0	22.5	31.4	-14.7
	Total	208.3	100.0	174.9	100.0	19.1

Source: Adapted from IDC Press release, October 20, 2005, www.idc.com

Samsung's catch-up stage (1984-1993)

As shown in Table 6.4, Samsung's telecommunication business has undergone consistent and rapid expansion in terms of technological expertise and sophistication. Although Samsung had started its electronics and computer businesses in the late 1970s, the entry of Samsung into the mobile communication industry did not start until 1983 when the firm started manufacturing basic telecommunication networks and devices. A new business unit named the Wireless Development Team was established with forty engineers, whose experiences had been in the wireless telephone or facsimile machine divisions. The team first focused on reverse-engineering car phones from Japan. The team finally produced and sold its first built-in car phone in 1986. However, the quality of the product was not satisfactory, and the firm decided to reduce the number of engineers in the Wireless Development Team to only ten. (Lee and Lee 2004)

Despite the setback, Mr. Ki Tae Lee, who was the team leader and now President of Samsung's Telecommunications Division, decided to keep trying on the mobile business. This time, the team tried reverse-engineering Motorola's mobile phones. Their efforts started to bear fruit in 1988, when Samsung developed the SH-100, the first cellular phone to be designed and produced in Korea. Despite the improvement in quality, Samsung's mobile phones were still regarded to be inferior to Motorola's mobile phones. (Lee and Lee 2004).

Table 6.4: Technological Milestones of Samsung's Telecommunication Businesses

Year	Milestones
2005	World's 1st Demonstration of Mobile WiMAX (802.16e)
2003	Providing W-CDMA Systems for SKT World's 1st Demonstration of CDMA2000 1X EV-DV at ITU Geneva 2003
2002	World's 3rd Major Handset Manufacturer World's First CDMA2000 1x EV-DO Commercialized in Korea DSLAM (1.16M Lines) Deployment for Chunghwa Telecom in Taiwan
2001	Commercial CDMA2000 systems Launch at SprintPCS (USA) CDMA2000 1X Deployment for China Unicom (China) World's 6th Major DSLAM Manufacturer
2000	World's First CDMA2000 1X System Commercialized DSLAM Deployment for Korea Telecom in Korea
1999	Developed World's First IMT-2000 Handset, System and Core Semiconductor Chips World's First CDMA2000 Video Telephony ESS Deployments exceeded 10M Lines ATM Switch (STARacer) Commercialized in Korea, U.S.A(Teligent Networks)
1998	CDMA Systems Deployment in Hutchison (Australia)
1997	Signed Worldwide Olympic Partnership contract and Sports marketing CDMA Systems trial in Shanghai, China
1995	World's First CDMA systems Commercialized in SKT, KTF
1988	Mobile phone, SH-100, developed, based on Motorola's mobile phones
1986	Built-in car-phone, SC-100, developed, based on Japanese car phones
1985	ESS (TDX-1A) commercialized in Korea
1983	Wireless Development Team established
1977	Samsung Telecommunication established

Source: Adapted from Samsung website: www.samsung.com; Lee and Lee (2004)

Samsung as fast follower (1993-1996)

The significant breakthrough for Samsung's mobile business occurred in 1993, after two important decisions. First, the Wireless Development Team shifted its focus onto improving connectivity, such that the mobile phones could function well in Korea's mountainous terrains and topography. Another significant decision was prompted by the so-called "Fukuda Report" written by Fukuda Shigeo, a Japanese design advisor to Samsung's Chaiman, Kun Hee-Lee.

The report focused on Samsung's problems in design and development practices and processes. This report led Chairman Lee to launch "Samsung New Management", an initiative that focused on corporate change, especially on quality improvement. As part of the New Management, the mobile phone business was given an ultimatum to "produce mobile phones comparable to Motorola's by 1994" (Lee 2002). Finally in November 1993, Samsung unveiled its new model, the SH-700, and the improved model, SH-770 in October 1994. Soon after that, Samsung started to show its technological breakthrough in 1993, when it developed the lightest mobile phone of its era, the SCH-800. This series of developments laid a strong foundation for Samsung to become a leading manufacturer of mobile phones with reliable quality and connectivity. By the end of 1995, Samsung surpassed Motorola to become the market leader of mobile phones in the Korean market. (Lee 2002; Lee and Lee 2004)

Although Samsung was a minor player during the first-generation mobile technology, during the second-generation stage, the company emerged as one of the main partners in the Digital Wireless Telecommunication System Project, led by the Korean Ministry of Communication (later changed to Ministry of Information and Communication) and managed by the Electronic and Telecommunications Research Institute (ETRI). Other domestic firms that participated in the project include LG Information and Communications (later merged as part of LG Electronics), Hyundai Electronics, and Maxon Electronics. A US-based firm, Qualcomm also participated in the project as the provider of CDMA technologies.

Samsung as leader (1996-present)

After building its technological capabilities in the 0G and 1G technologies, Samsung surged ahead as a leading manufacturer of the 2G CDMA phones. Samsung released its first CDMA cell phone, the SCH-100, in March 1996, the same time as the launch of CDMA mobile services offered by SKT and Shinsegi Telecom. Within a year of the release, Samsung captured a 57% world market share in the CDMA market and 58% in the PCS market.[51]

Since then, the telecommunication business became increasingly more important for Samsung. Although Samsung had been successful in the semiconductor business, the firm faced difficult times during the mid-1990s, with poor performance particularly in the appliance businesses. The financial crisis in 1997 further worsened the situation. In response to the downturn, Samsung started to overhaul its management and operation. As part of the restructuring and reorganization, Samsung allocated more of its resources and efforts to the telecommunication and LCD businesses to diversify its revenue sources. (Lee and Lee 2004)

Building on its domestic success, Samsung expanded into the global market, first in the CDMA-based U.S. market, and then the European GSM market. Its first deal with Sprint, an American CDMA service provider, became the springboard for Samsung to expand into other emerging CDMA markets, such as Hong Kong and Brazil. By 1999, Samsung became the world leader in the global CDMA handset market. (Lee and Lee 2004)

Samsung continues to demonstrate its technological capability and leadership into the third-generation era. As the 3G CDMA2000 1x EV-DO services were first commercially available in Korea in 2002, Samsung was the leader in providing the 3G handsets. Samsung also provided W-CDMA Systems for SKT when the service provider demonstrated its CDMA2000 1X EV-DV system at the ITU in Geneva in 2003. In 2005, Samsung launched the world's first Mobile WiMAX.[52] Samsung's remarkable technological success is a manifestation of its relentless R&D activities, and, more recently, its standards efforts.

Samsung's participation in mobile telecom standardization

During the catch-up and keep-up stages of Samsung's technological development in mobile communication, its main standards activities focused mainly on learning the specifications and requirements of existing standards developed by technology and standards leaders. When mobile communication services were first launched in Korea, Samsung imported handsets from Toshiba in Japan, based on the U.S. AMPS standards.

Samsung's standards activities became more evident and important during the time of the 2G CDMA standards. Samsung became one of the main partners in the CDMA consortium led by the Korean government. It became more active in participating in standardization activities first in the consortium and later in other domestic and international standards forums.

The number of standards organizations in which Samsung participates has increased dramatically since the firm increased its efforts in developing handsets and other equipment based on the 2G CDMA standards. According to our interviews with Samsung engineers, Samsung Electronics participated in only about a few standards forums in the early 1990s, and fewer than 10 organizations by the end of 1990s.[53] As of April 2005, Samsung Electronics participates in approximately 70 standards organizations at the regional and global levels, including industry consortia, alliances, and formal standardization bodies. This figure accounts for all of the five main business units of Samsung Electronics, namely, Semiconductor, Telecommunication Network, Liquid Crystal Displays, Digital Media, and Digital Appliances. The Telecommunication Network Business alone accounts for approximately 20 standards organizations, including standardization forums in other countries and regions, such as Japan-based ARIB and France-based ETSI. This does not include another 31 domestic forums that have been arranged and facilitated according to the IT839 Strategy of the Ministry of Information and Communication (MIC) and the Korean Telecommunication Technology Association (TTA). Samsung participates in most of the 31 domestic forums.

Samsung Electronics has now become a standards leader in various telecommunications areas. For instance, the company is a co-sponsor of WiBro (Wireless Broadband) Standard, a wireless broadband internet technology developed by the Korean telecom industry. WiBro is a rival to WiMax, the current U.S. Wireless Wide Area Network (WAN).[54] In September 2005, Samsung signed a deal with Sprint Nextel to provide equipment for a WiBro trial. This indicates Samsung's leadership in mobile telecom standardization.[55]

Samsung's personnel in leadership positions in standards forums

We have demonstrated earlier the leadership roles that Samsung's engineers and executives play in the standardization activities of semiconductor industry. Similarly, Samsung's leadership in telecommunication standardization is indicated by its personnel holding important leadership positions in international SDOs. Notably, Dr. Young Kyun Kim, Senior Vice President in Global Standards and Research of Samsung Electronics, has been a prominent figure in telecommunications standardization at the global level. Since 2001, he has served as Vice Chairman of ITU-T SSG on IMT-2000 & Beyond. He has also served as Vice Chairman of the Asian Asia-Pacific Telecommunity Standardization Program (ASTAP) for the standard activities of the Asia-Pacific region and also as a Chairman of APT IMT-

2000 Forum promoting mobile communication services (2G/3G) into this region. In addition, he has been a Steering member of other standards consortia, including 3GPP PCG/OP, 3GPP2 SC/OP, CDG, OMA and WWRF. At the domestic level, Dr. Kim serves as a Vice Chairman of Technical Committee and Chairman of Program Evaluation Committee and an Advisory Board member of the Korean Telecommunication Technology Association (TTA).

Dr. Young Kyun Kim has been Senior Vice President of Global Standards and Research at Samsung since 1999. He is responsible for overall global standards and strategy development within Samsung Electronics. Under his supervision is the team Beyond 3G, which works on system research & standards and optical and IP networking standards research. With his leadership, in 3G standards both 3GPP and 3GPP2, Samsung Electronics has achieved a worldrecognized technology standards position.

There are several reasons why Samsung, and for that matter, other Korean late standardizers, have increased their engagement in telecommunication standardization. One reason is the competition from low-cost latecomers, especially from China. Although Korean latecomers were successful in low-end, low-technology products, technologies are maturing quickly and other latecomer firms started to compete directly against them. This forces Korean latecomers to move up the technological ladder quickly enough to avoid the lower-cost competition. Meanwhile, in order to compete against the technological forerunners, they need to be able to acquire advanced technologies for new products. At the beginning, this meant they had to license proprietary technologies from the forerunners.

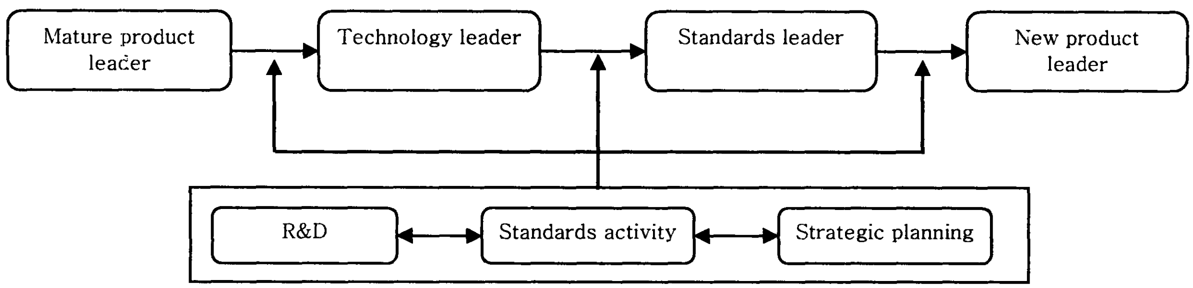
One strategy for Samsung was to diversify into higher-end products. Standardization helps achieve this goal. This may seem paradoxical, as standardization normally propels commoditization of products, thereby lowering profit margins. Yet, for first movers who are quickly and constantly developing new products, standardization could allow them to utilize the limited windows of opportunity to reap profits before their competitors. Standardization means rising demand at the earlier production stages, which give the first movers the chance to reap profits before other latecomer firms. In many industries, particularly ICT industries, profits decrease sharply after products are standardized, so leader firms have a greater chance to reap profits if they know beforehand what "the next big things" are going to be.

Again: Quality standards are the key

As with the case of semiconductor businesses, quality standards and management play a key role in successful late standardization and technological catch-up process in the Korean mobile communications sector. The growth and transformation of Samsung Electronics into one of the top global brands is its continuous effort on quality standardization and control. Another indication of Samsung's commitment to product-quality improvement is its policy to recall and destroy whole production lots of mobile phones when defects are found.[56]

An important set of quality standards and tools for the telecommunications industry is TL 9000 standards. TL 9000 was developed by the Quality Excellence for Suppliers of Telecommunications (QuEST) Forum, which is the telecommunications industry's extension to ISO 9001:2000. TL 9000 defines the quality system requirements for design, development, production, delivery, installation, and maintenance of telecommunications products and services. It adds additional stringent requirements to the basis for quality provided by ISO 9001.[57] In addition to ISO 9000 series, TQM, TPM, etc., Samsung became TL 9000-certified producer of fiberoptic products with the certification through the US-based National Quality Assurance, Inc. Samsung achieved TL 9000 certification for optical fiber and cable, connectors in July 2000, for optical modules in November 2001.

Figure 5.1: Samsung's Leadership Sequence in Semiconductor



LG ELECTRONICS

Another outstanding Korean late standardizer is LG Electronics. The firm is now a leading global firm in the LCD and telecommunication industries, in addition to its stronghold in home-appliance sectors. Similar to Samsung, LG Electronics has in recent years demonstrated technological and standards leadership in the ICT sector. In this section, we examine LG's standardization activities and discuss how the firm uses standards activities as the linking and learning mechanism to move from a latecomer position to a fast-follower position and finally a first-mover position in the mobile communication and other related industries.

Overview LG Electronics

LG Electronics was established under the name Goldstar in 1958, and later changed to the current name in 1995.[58] LG Electronics was indeed the pioneer in the Korean consumer electronics market, having produced Korea's first radio in 1959, first telephone in 1962, and first black-and-white television in 1966, first air conditioner in 1968, and first washing machine in 1969. Its strength has continued to these days in the consumer electronics sector. Particularly in the liquid crystal display (LCD) market, LG has gained and sustained its reputation as one of the global leaders in terms of market share and technology, since it formed a joint venture with Philips, LG-Philips LCD, in 2000.

LG Electronics is now a global company in electronics, information and communication products with the annual sales of US $38 billion in 2004. LG Electronics is ranked fourth in terms of both shipment and market share in the global mobile handset market (Table 6.3).With more than 66,000 employees working in 76 subsidiaries in 39 countries, LG is comprised of four main business companies, including Mobile Communications, Digital Appliance, Digital Display, and Digital Media.[59]

LG's technological development in mobile communication

LG is rapidly becoming a global leader in mobile handsets, especially in CDMA, GSM and 3G mobile phones, exporting its products to approximately 70 countries worldwide. LG's technological capability has improved significantly in recent years. LG is now striving to lead the global mobile service industry with development of cutting-edge, trendsetting mobile handsets. It was in fact the world's first company to unveil a CDMA platform-based digital mobile phone. In 2003, LG developed the world's first synchronous-asynchronous IMT-2000 mobile phone for 3G mobile technologies. As a result, LG is now ranked fourth in the global mobile handset market, in terms of total annual shipment and market share (Table 6.3).

Particularly for CDMA handsets, LG is ranked second behind Samsung with a 19% market share, ranked second as well for WCDMA handsets with a 22.8% market share, and ranked sixth for GSM handsets with a 3.8% market share.[60] Within the U.S. market, LG is ranked first in terms of sales of CDMA phones in the United States for the fourth quarter of 2003.[61]

LG's successful late standardization

LG Electronics has been participated actively and successfully in standardization activities in several technological areas. One of the most notable is in Digital Television (DTV) standards. LG has developed the enhanced vestigial sideband (EVSB) standard for the next-generation DTV transmission technology. This EVSB technology was chosen in 2004 to be the US/Canada DTV transmission standard by the Advanced Television Systems Committee (ATSC), which is the voluntary standards forum for digital television in North America. This adoption indicates that LG has, at least in this area, become not only a technology leader but a standards leader at the technological frontier.[62]

LG's technology and standard leadership has become eminent as well in the area of digital media broadcasting (DMB).[63] Currently, there are four mobile broadcasting standards in the world: South Korea's DMB, Europe's Digital Video Broadcasting-Handhel (DVB-H), Media Forward-Link-Only (FLO) of the United States, and Japan's Integrated Services Digital Broadcasting (ISDB-T). South Korea is considered the leader in this area, with its first satellite and terrestrial DMB services being offered for the first time in the world, respectively, in May and December 2006. LG Electronics and Samsung Electronics are two of the main parties behind the DMB standardization and implementation in Korea.

In preparing for the launch of DMB services, LG developed the world's first Digital Media Broadcasting (DMB) phone in 2004. In January 2006, both LG and Samsung launched the first handset models based on the DVB-H and Media FLO mobile broadcasting standards for the European and U.S. markets. The fact that both LG and Samsung are able to produce products across different standards for digital mobile broadcasting indicates their advanced technological and standards capabilities. In addition to the R&D capability, their participation in standards forums enables both firms to forge ahead as the standards leaders in this technical area. Both companies participate in the FLO Forum, which supports the Qualcomm-conceived FLO standards, and the DVB Forum, which supports the DVB standards.

Another indication of LG's standards leadership is its initiative to found new standards forums that serve the firm's technological portfolio and strategic interests. One of the standards forums that LG has founded is the LnCP Consortium for standardization of Living Network Control Protocol (LnCP). This is the world's first management standard for the home network. The LnCP members include home network developers and manufacturers, such as Daewoo Electronics, SK Computer & Communication, and Honeywell Korea. As an indication of LG's leadership in the initiative, other consortium members have adopted LG's application programming interface (API) technology to develop their networked appliances.[64]

LG personnel in leadership positions in standards forums

As argued earlier, late standardizers' standards leadership is manifested through its employees being selected for leadership positions of standardization forums. This is also the case for LG Electronics, which has demonstrated its leadership in setting the global standard of 3G CDMA mobile communications. Dr. Byung-kwan Lee, an Executive Researcher (Vice President) at LG Electronics Telecommunication Equipment & Handset Business, was appointed as a chairman of TSG-C (Technical Specification Groups - CDMA2000) in the 3GPP2 meeting in China in 2004. He led TSG-C in developing the global standard of CDMA2000 handset and networks, and represented 3GPP2 in its meetings with 3GPP or other UMTS/WCDMA standard development organizations. As described in the previous chapter, 3GPP2 was established in 1999 with a goal of setting global standards of 3G CDMA system or CDMA2000 mobile technologies. By working with various standards forums in the United States, Japan, China, and Korea, 3GPP2 has worked on the global standards for improving wireless connection technologies, applying new multimedia services such as MMS and developing IP systems for all the networks.

The appointment of Dr. Lee means that the world mobile communication industry has recognized LG Electronics for its active development of CDMA mobile communications' standards and will consolidate Korea's position as the world's first developer of CDMA. Lucent Technology has chaired 3GPP2 TSG-C for the last four years. For the new chairmanship, LG Electronics was selected after an uphill battle with Ericsson.[65]

KT Corporation

Korea's successful late standardizers are not limited to handset and equipment manufacturers, such as Samsung Electronics and LG Electronics. The service providers, notably SK Telecom (SKT) and KT Corporation, are also the key players and therefore important players in the Korean late standardization process. In this section, we discuss KT's late standardization process in the mobile communication industry.

Overview of KT Corporation[66]

KT Corporation is South Korea's largest telecommunication company. The company is one of the largest telephone companies in South Korea, and one of only two companies licensed to provide local telephone access. KT''s mobile communication business is operated by its subsidiary, KTF (Korea Telecom Freetel). The company boasts thousands of locations and 12 million subscribers in South Korea.

KT was established as a state-owned telecommunications company in 1981 through the enactment of the Korea Telecom Act. The company officially took over the telecommunications business being operated by the government through the Ministry of Information and Communication (MIC - formerly Ministry of Communication) in 1982. In 1997 the Korea Telecom Act was repealed and Korea Telecom became a corporation with limited liability under the Commercial Code of 1997. The company was fully privatized in 2002 and changed the name to KT Corporation.

During its initial stage of development, KT focused on supplying general-purpose telephone facilities and services to the domestic market. By 1984, KT was successful in developing the world's 10th electronic switch TDX-1 for domestic use. Meanwhile, the number of telephone lines in Korea increased from 4.5 million in 1982 grew to over 20 million in 1993. Such an increase was the harbinger for the era of "informatization" for South Korea. KT has since become Korea's leading telephone service provider with nationwide coverage for fixed-line communication networks and over 20 million subscribers.

In 1994, for the first time in Asia, KT laid up-to-the-second Internet and satellite communication networks that served access points across the world. After KT was converted into a government-invested corporation in 1997, it went through a substantial reform, shifting its focus onto wired-wireless-Internet businesses. To that end, the Asymmetric Digital Subscriber Line (ADSL) service was introduced to the nationwide information superhighway infrastructure. This positioned KT as the leading high-speed Internet service provider. In addition to its extensive wired coverage, the acquisition of Hansol M.com in 2000 and joint services with KTF, a KT subsidiary, further enhanced wireless communications services.

KT entered the high-speed Internet market as a late bloomer in 1999. In June 2000, just a year later, KT seized the number one position in the same market. This was followed by a landmark achievement in September 2000 when KT subscribers surpassed the one million mark, the highest number ever reached among local telecom players. KT established itself as one of the world's best broadband service providers when its number of subscribers grew to four million by March 2002 and five million by January 2003.

Since 1999, KTF has expanded its operations to overseas. In 2003, KTF received an order from PT Mobile-8 Telecom of Indonesia for a comprehensive consulting service. The firm also signed a contract for the export of its CDMA network management system and invested US$10 million in the Indonesian provider. In India, KTF completed the first stage of its contract with Reliance for US$2.65 million worth of the CDMA network construction. KTF also holds a 25% stake in CEC Mobile of China, after investing a sum of 4.5 billion won in 2002.[67] These overseas projects indicate not only KTF's marketing capability but also ithe underlying technological capability and experiences in CDMA technologies.

Standards Activities of KT

KT has become increasingly active in domestic and international standardization. As of April 2005, KT participates in 12 international standardization forums, seven of which are industry consortiums. On the other hand, KT participates in 16 domestic standards forums, including the TTA, which is the official standards development organization for information and communication technology in Korea. KT's engagement in international standardization is measured in terms of its participation and contribution. As of 2005, KT has annually about 20 experts in 40-50 meetings and contributes around 40-50 proposals and technical opinions in international standardization initiatives.

Table 6.5: KT's Standardization Activities, as of April 2005

International Standards Forum		Domestic Standards Forums	
Formal SDO	Consortium	Formal SDO	Consortium
International Telecommunication Union (ITU) Asia Pacific Telecommunity (APT) ISO/IEC/JTC1 IETF IEEE	– Multiservice Switching Forum (MSF) – DSL Forum – IPv6 Forum – Optical Networking Forum (OIF) – Parlay Group – Telemanagement Forum (TMF) – VoiceXML Forum	Telecommunication Technology Association (TTA)	– BcN Forum – Wireless LAN Forum – DRM Forum – IPv6 Forum – LBS Association – MPEG-Korea – UWB Forum – Optical Internet Forum – Voice Recognition & Processing Association – Web Korea Forum – Internet Telephony Forum – Future Broadcasting Forum – Future Mobile Service Forum – Korea Bluetooth Forum – Korea RFID/USN Association

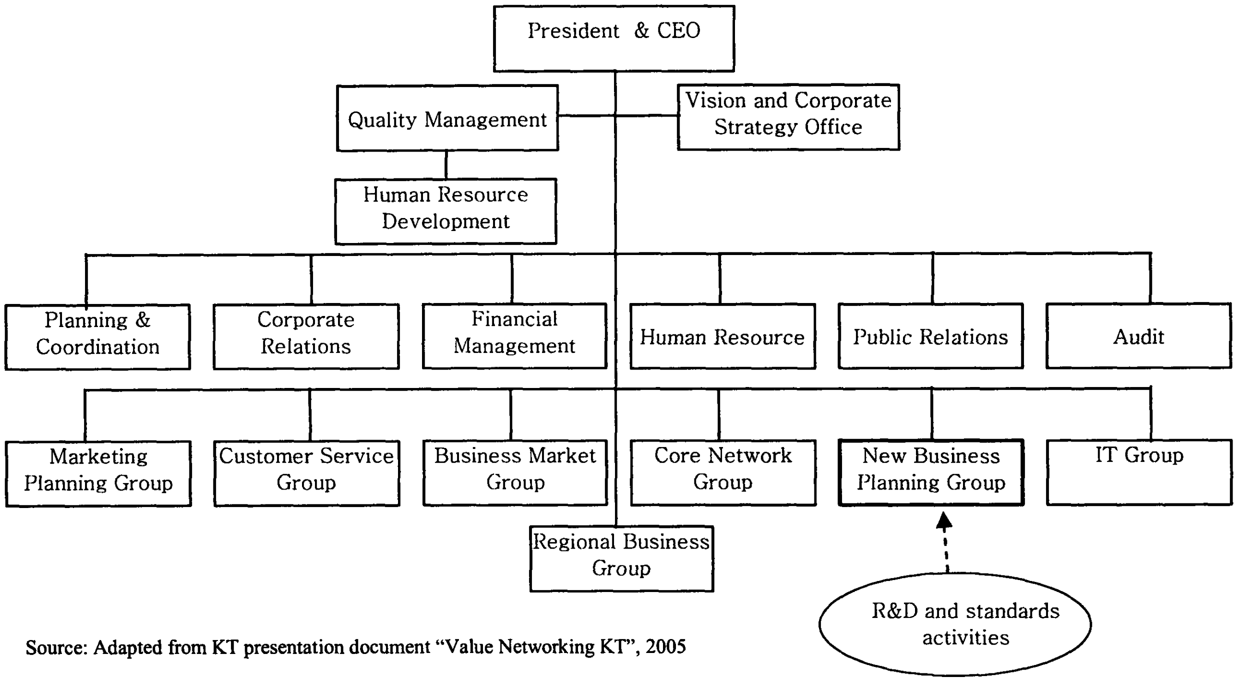
Source: KT's internal document, and interview with a KT standards expert, April 2005

Note: SDO stands for Standard Development Organization

Meanwhile, KT's personnel have assumed leadership positions in international SDOs. Not only has KT increased its participation in international standardization, but the company has also become more active in assuming leadership role at these standards forums. This indicates its standards leadership at the international level. The SDOs that KT's personnel assume chairmanships include ITU-T SG2 (as Vice Chairman and Associate Rapporteur), ITU-T FG NGN (as Chairman), ITU-T WG3 (as Co-chair), ITU-T SG13 Rapporteur, and Multiservice Switching Forum (MSF) (as a Board Member).

KT's standards activities are conducted within the New Business Planning Group, a de facto R&D Group of the company (Figure 6.1). It is within this Group that several new standards and technologies have been developed and tested, including ADSL Service, IMT-2000 systems, and NESPOT (WLAN) technology. During the 1980s, KT's R&D efforts were spread across all domains of telecommunication services. KT adjusted its R&D strategy in the mid 1990s, putting more emphasis on technical areas closely linked with the businesses. Since 2000, its R&D efforts have become more strategic, focusing on exploring new business opportunities and customer-oriented services. Standards activities at KT have become even more important since the mid 1990s, and have become a crucial element of R&D activities.

Figure 6.1: KT's Organizational Structure, as of 2005



Source: Adapted from KT presentation document "Value Networking KT", 2005

ORGANIZATIONAL STRUCTURE FOR STANDARDS ACTIVITIES

Successful late standardizers accommodate standards activities through appropriate intra-firm organizational structure. They organize their R&D teams in such a way that standards-related activities are a key part of their corporate strategy, not to mention a core part of their R&D strategy. In all of our case studies, successful late standardizers centralize standards-related R&D units within the R&D headquarters close to top decision-making. They also adjust their internal human resources structure, such that standards personnel stay longer in one department, rather than changing roles from one department to another.

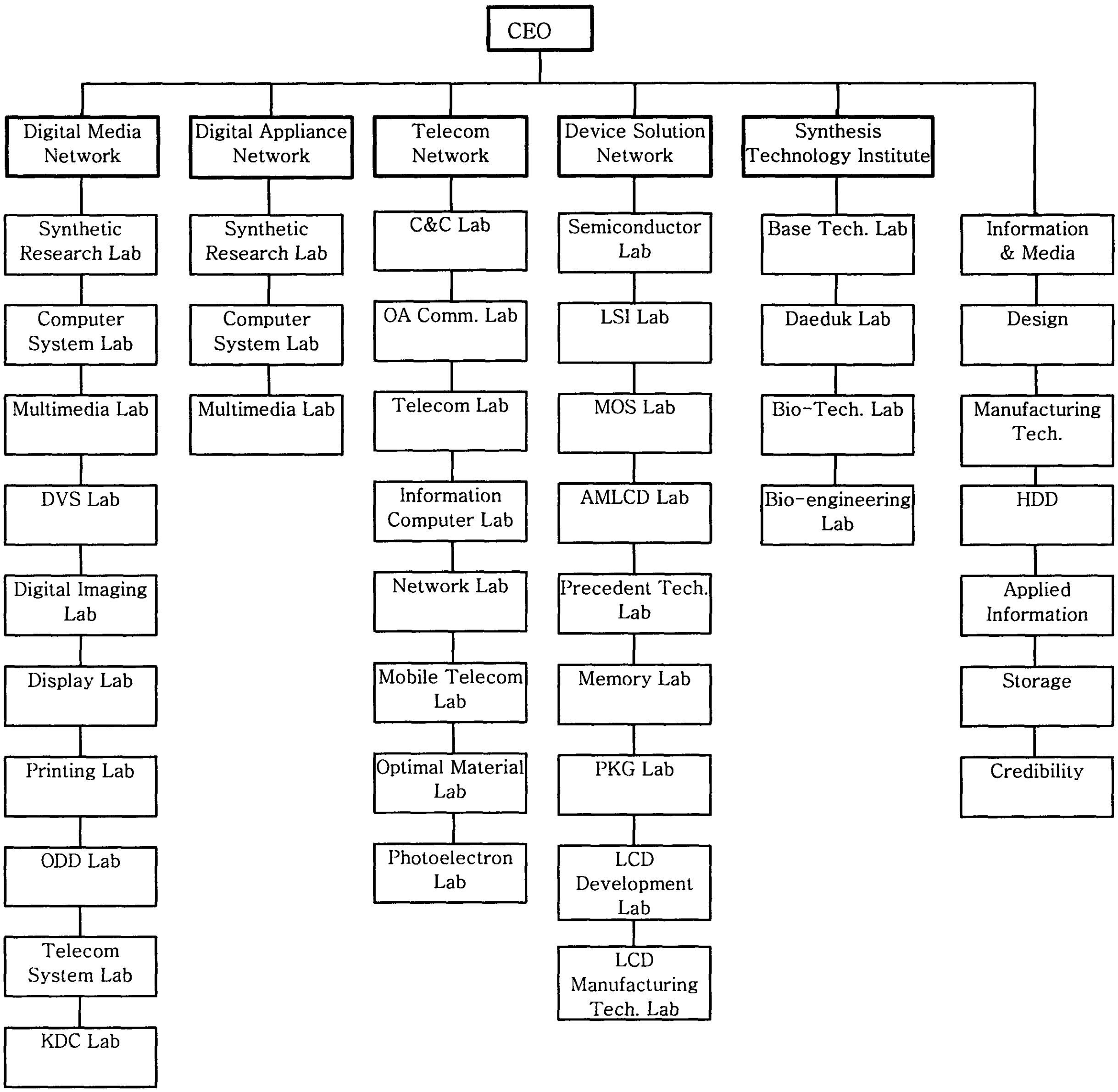
CENTRALIZED R&D FOR STRATEGIC STANDARDIZATION

Samsung Electronics, LG Electronics, and KT centralize their standards units in their R&D headquarters near Seoul, even though both companies have R&D labs and centers in other countries. These units work on standardization activities, which involve mostly the engineering design activity that eventually leads to new products or processes.

Samsung Electronics, for example, has formed the Global Standards & Research Team within the Telecommunication R&D Centre in Suwon city, outside Seoul. Its standards activities are an important element of its R&D activities. The standards activities for telecommunications are located in the Samsung Electronics Digital Research Center. The R&D center is claimed by the company to be the largest R&D center in Asia, with approximately 5,000 in-house researchers. Many of its R&D labs, shown in Figure 6.2, are located in the Digital Research Center in Suwon.

Another important organization that plays a crucial role in Samsung's standards activities is the Samsung Advanced Technology Training Institute (SATTI). Established in 1990, SATTI has been taking charge of R&D in Samsung Electronics. In 1998, SATTI also went through reorganization in accordance with the company's long term strategic goals. Since then, training has been on-site, problem-solving and trainee-centered, and it has systematically trained core engineers of the company. SATTI now focuses on training engineers in the areas of 3S (software, systems and service) and basic technology, which is common to all products manufactured by Samsung.

Figure 6.2: Samsung Electronics' R&D Organizational Structure



Source: Lee and Lee (2002) from Samsung Electronics Business Report 2003

In the case of LG, its telecom standards activities are conducted within the Mobile Communication Technology Research Lab, located in its R&D Center in Anyang City, near Seoul. One key element of LG's R&D strategy is to map out new standards in newly emerging areas. Its recent focus is on new standards-based technologies that link the Internet and other mobile communications. LG's standards activities are often jointly between various business and technical areas in the company. Yet, most of these activities are located in the same R&D Center in Anyang.[68]

Similarly, KT's organizational structure for standards activities is centralized. Its standards activities are conducted at the Woomyeon-dong Research Center in Seoul, in which the R&D headquarters and the Technological Investigation & Evaluation Center are located. Although KT has recently agreed to build an R&D Center with Microsoft and another one with Alcatel of France, both R&D centers will be located in Soul. Not only does this indicate the technological capability of KT, but also the availability of specialized human resources in Korea in the field of mobile communication.

Our interviewees from Samsung, LG, and KT all agree that standards activities are strategic in nature. Close proximity to top-decision making and to related R&D activities is important. There are instances in which experts from various technical and business fields need to provide their inputs before strategic standards-related decision can be made. The centralized nature of standards activities thus reflects the need to keep strategic R&D activities close to top decision-making at its R&D headquarters.

In addition, as many innovative ideas can easily leak or get "stolen" by simple observation, these companies implement various measures to keep their R&D plans and activities secret. In addition to security measures at their R&D centers, they hope to prevent "knowledge spillovers" by centralizing standards and other R&D activities in single sites.

ALLOCATION OF HUMAN RESOURCES FOR STANDARDS ACTIVITIES

Successful late standardizers adjust their internal human resources structure, such that standards personnel stay longer in one department, rather than changing roles and responsibilities from one department to another. The underlying rationale is that standardization requires constant and persistent external relations with other firms in standards forums. Personal connections become critical for late standardizers that aspire to establish their foothold in standardization forums to become standards leaders themselves. Other people in standardization forums are familiar with each other. They have worked together for a long time. However, the problem with Samsung Electronics and LG Electronics, which they are trying change, is that engineers do not stay in the same division long enough for standards activities. They often move to different units after a few years, and once they are promoted, they move to other divisions and no longer work on standards-related issues. This means a new person has to take over the existing standardization projects.

STANDARDS AND INTELLECTUAL PROPERTY

Standards are often directly tied to intellectual property rights (IPR), especially industry voluntary standards. Once late standardizers develop more technological capability, they increase the linkage between standards activities and intellectual property protection. As firms invest more in R&D and are able to produce more intellectual property, they search for ways to generate and appropriate rents from their proprietary technologies. One important mechanism is to develop standards that include their proprietary technologies. Chances are that if a firm is involved in R&D of a new technology, there is at least one standards forum exploring the potential to standardize such technology.

Intellectual property issues affect the development and diffusion of standards in various ways. By contributing their proprietary knowledge to standards development, firms hope to gain from the eventual outcome, i.e., standards, either by having such technologies incorporated in their new products or by licensing such technologies to other firms that want to adopt the standards. Such an expectation is assured only when it is guaranteed that their proprietary knowledge will be protected. This is when legal protection in the form of patents and trade secrets becomes critical. Meanwhile, during the process of standards development, there are usually uncertainties regarding intellectual property rights associated with the technologies contributed by forum members. One general uncertainty is whether patent owners will actually grant licenses to other firms once their technologies are included in the final standards. Then, another question arises as to how much the license costs will be and whether they will affect the diffusion of such standards. There is also a possibility of patent infringement in standards development, due the timing of patent application and assertion by firms whose technologies are included in standards. All the uncertainties related to intellectual property often result in litigation among parties that are involved in standards development.

Legal capabilities, especially those related to intellectual property, thus become an indispensable part of standards capabilities. Legal capabilities include not only the ability to deal with litigation and lawsuits, but also the ways in which technical experts should participate in standardization activities.

Even though there are always risks involved, firms often gain from participating in the standardization of new technologies. For instance, even when technology owners follow the requirements to disclose their intellectual property to other members in standards forums, they still benefit from having their proprietary technologies included in standards. A good indication is the increasing participation in international standardization by three major Korean firms in the mobile communications industry, namely Samsung Electronics, LG Electronics, and KT. As several scholars argue (e.g., Lee and Lim 2001; Yoo et al. 2005), one major reason for their increasing efforts in standardization is their large royalty payment to Qualcomm for the core CDMA technologies used for mobile communications. Most of the royalty payments by Samsung Electronics and LG Electronics are based on sales volume. This means an increase in total sales results in greater royalty payments. As with the case of leading firms, such as Intel and IBM, successful late standardizers, such as Samsung, have established intellectual property licensing within their profit-and-loss businesses, not just a part of their legal department.

Our interviews with executives in mobile communications businesses of Samsung, LG, and KT, confirm this argument.[69] According to these executives, royalty payments are an important factor that motivates the firms to engage more in technological standardization. It is reported that Qualcomm receives 5.25 percent of annual domestic sales of handsets in royalties and 5.75 percent of exports from Korean manufacturers.[70]

According to its Audit Report for Year 2004, Samsung Electronics spent a total of 1.28 trillion won (1.3 billion USD) on royalty payments to other domestic and foreign companies in 2004, an increase of 5.6 percent from 2003. The figure has increased significantly from 772.1 billion won (772 million USD) in 2001 to 965.7 billion won (966 million USD) in 2002 and further to 1.2 trillion won (1.2 billion USD) in 2003. While the increasing rates in royalty payment have somewhat subsided, in 2004 the amount still accounts for 11.8 percent of its net profit of 10.7 trillion won (10 billion USD). Although the rise in royal payments indicates its sale growth, it also implies the continued reliance on other companies for advanced technologies. The efforts and engagement in standardization is one way in which these late standardizers attempt to become more technologically independent.

CROSS-LICENSING, PATENT POOLS, AND STANDARDS

Another important outcome of participating and contributing to standardization is that late-standardizing firms are able to join a patent-pool for a standard or a cross-licensing agreement with technological leaders in the same standards clubs. A cross-licensing agreement allows the two parties to grant a license to each other for the use of the subject-matter claimed in patents. Cross-licensing is thus the mutual sharing of patents between companies without an exchange of a license fee, providing that both patent portfolios are deemed about equal in value. A patent pool, on the other hand, is a group of at least two companies agreeing to cross-license patents and other intellectual property rights relating to a particular technology. By creating a patent pool, technology sellers (patentees) and technology buyers (licensees) could save time and money.

There are four common features of patent pools (Kulbaski 2002). First, a patent pool is appropriate for a definite and well-defined technological standard. Second, there is an evaluator or an independent expert to determine which patents are essential to the standards in question, thereby defining a group of essential patent holders. Third, essential patent holders draft and approve a license which allows others to license technology on a reasonable and nondiscriminatory basis. Fourth, the essential patent holders appoint a patent-pool administrator to handle the administrative tasks. Finally, essential patent holders reserve the right to license the patents outside of the patent pool.

Patent pools reduce search and transaction costs for both licensors and licensees. Patent pools facilitate efficient transactions, as a firm using the technology does not need to negotiate separate licenses with every company owning a patent that is essential to the standard. Both licensors and potential licensees are able to identify quickly what patents are essential to the standard in question. Pool members may also be able to control IPR cost-element in certain products based on the standards in the patent pools. Patent pools thus reduce operational costs and allows members to receive more licensing revenues. In addition, patent pools also reduce the possibility of litigation regarding IPR infringement (Shapiro 2001). A potential problem that may occur regarding IPR derived from standards is the issue of collusion and antitrust violation [71] Participants in patent pools generally seek antitrust approval from relevant regulatory agencies in important markets, particularly the United States, the European Union, and Japan.

In the case of Samsung, the increase in cross-licensing agreements with other foreign firms offsets the increase in the company's royalty payments in 2004. Many of Samsung's patents were licensed by other firms, because they were essential to certain standards. Certainly, patent-pooling and cross-licensing would not be possible without latecomers' selfowned patents, which in turn are an outcome of its intensive R&D efforts. Cross-licensing and patent pools are ways for late standardizers to gain access to larger pools of intellectual property with reduced costs, and to generate revenues from their proprietary technologies.

The revenue-generating benefit of participating in standards development is well recognized by Samsung and LG executives. One LG executive mentioned that participation in standards development is a logical step for the company. The firm had invested substantially in R&D, and, as a result, has generated new ideas, innovations, and finally secured patents. In other words, participation in standardization is a way to recoup R&D investments.

As late standardizers develop technological and standards capabilities, IP licensing gains significance as a separate profit and loss business. Organizationally, it becomes a distinct unit within the firm, not just within the legal department.

Generally, patent pools do not include every firm that participated in developing a standard. They include only a group of firms that hold "essential" patents to the standard. Essential technologies included in standards are, therefore, the core technologies that underlie the directions of the related technologies both in the present and the future.

The use of patent pools is not new. Currently, several patent pools have been formed that are linked directly to standards, including the MPEG Licensing Administrator (MPEG LA) pool for MPEG technologies and the DVD 7C pool for DVD standards. The MPEG LA provides a license to those requiring the essential patent rights to MPEG-4 technology. Using MPEG LA is the easiest, most cost-effective way to obtain the rights to complex and highly developed technology. The MPEG-4 Patent Portfolio Licenses currently include patents owned by more than twenty companies, including LG Electronics and Samsung Electronics.

The intent of this patent pool is to provide users worldwide access to all MPEG-4 essential intellectual property through one organization that grants licenses and collects royalties.[72]

Thus, there is a different license to make and sell a product meeting the standards, from the license to use the product in certain commercial applications. MPEG-LA established the precedent for use fees with the MPEG-2 license, which requires DVD manufacturers to collect a small royalty on each DVD they manufacture that uses MPEG-2 compression.

IPR holders in standards may offer one license to make and sell a compliant product or service and a separate license for the use of the product or service. The AVC Patent Portfolio was recently issued by the MPEGLA. The AVC/H.264 license sets conditions for one of the highly competitive and state of the art video compression systems. Multiple patents are required to implement the AVC standard. Table 6.6 shows details of the two patent pools. In the MPEG LA patent pool, Korean late standardizers show strong presence in terms of number of licensors and patents. Samsung and LG are two Korean firms among 25 licensors of the MPEG 2 standard, holding a total of 17 patents. The two firms and Curitel, another Korean firm, hold a total of 27 patents in the patent pool for the MPEG 4 visual standard.

Table 6.6: Number of Patents Held by Korean Late Standardizers in Patent Pools

Patent Pool	Field	Number of Licensors	Total Number of Patents	Number of Patents Held by Korean Companies
MPEG LA	MPEG 2	25	709	Samsung (17), LG (1)
	MPEG 4 visual	23	245	Samsung (14), Curitel (10), LG (3)
	MPEG 4 system	8	64	Samsung (14), ETRI (20)
DVD 7C	DVD	7	1,686	None

Source: Adapted from MPEGLA and DVD6 websites: www.mpegla.com and www.dvd6cla.com

Notes: (1) MPEG LA: Moving Picture Experts Group Licensing Administration

(2) DVD 7C LA: Digital Video Disk 6 Company Licensing Agency

(3) ETRI: Electronics and Telecommunications Research Institute

3G Patent Platform

Another noteworthy initiative to deal with proprietary technologies included in standards is the 3G Patent Platform, first established in 1998 to deal with patent concerns associated with third-generation (3G) mobile technologies. During that time, a large number of firms owned patented technologies deemed "essential" to the 3G mobile standards. The number of such firms was much larger than the case of 2G GSM standards, for which there were about 20 firms. Several standards development organizations working on the 3G standardization recognized the needs to establish an industry-wide arrangement to deal with the complexities and uncertainties of the intellectual property situation associated with 3G standards. As a result, 41 major international telecom companies jointly formed a working group within the UMTS Intellectual Property Association (UIPA) to define the specification for the 3G Patent Platform, which deals specifically with the IMT-2000 3G standard. [73]

During the implementation phase, a group of 19 major operators and manufacturers ("Partners"), four Promoters and two Associate Partners formed the 3G Patent Platform Partnership to seek antitrust approval from relevant authorities, including the Japanese Fair Trade Commission, the U.S. Department of Justice Antitrust Division, and the European Commission. They also set up institutional and legal frameworks for the Patent Platform. In January 2003, the 3G Patent Platform started its commercialization phase, by offering services to evaluate, certify, and license patents that are technologically essential for the manufacture and operation of 3G mobile communication systems. The W-CDMA Patent Licensing Program has become operational since January 2004. Table 6.7 shows the list of member firms in the 3G3P.

Table 6.7: Company Members of 3G Patent Platform Partnership (3G3P), 1999-2002

Partners		Promoters	
Manufacturers	Operators	Manufacturers	Operators
Alcatel	Cegetel	Huawei Technologies	GSM Association
Bosch	France Telecom	Kyocera	ETNO
ETRI	KPN	Sharp	
Fujitsu	KT	Telit Mobile Terminals	
LG Electronics	KT Freetel		
NEC	NTT DoCoCo		
Matsushita	Telecom Italia Mobile		
Mitsubishi Electric	SK Telecom		
Siemens	Sonera		
Samsung Electronics			
Sony			

Source: 3G Patent Platform website, www.3gpatents.com

Korean late standardizers constitute a large group in the 3G3P. LG Electronics, Samsung Electronics, KT, SK Telcom, and ETRL are partners of the group. This reflects the strength of Korea's technological capability in the area of 3G mobile communication as well as their effort to find ways to utilize their proprietary technologies.[74]

LEGAL CAPABILITIES

Because of the increasing importance of intellectual property and potential antitrust lawsuits, late standardizers need to improve their legal capability, which we consider to be an essential element of standards capability. Samsung Electronics, for instance, has a very capable legal department. Each of Sumsung's five major business divisions has its own intellectual property department. There is also an independent legal department whose task is to coordinate with each IP department concerning how to deal with any patent litigation.[75]

Samsung sometimes hire outside counsels to deal with intellectual property issues. The decision on the choice of outside counsel is usually made in a manager-level meeting.

Each company has its own guidelines and procedures regarding intellectual property generated by R&D activities. In Samsung, for instance, the intellectual property department in each business unit usually sets up a patent evaluation committee to review any possible inventions that its engineers have produced. The committee is to decide whether or not to file a patent or other intellectual property protection for an invention, where to file, and which route to take. The committee is usually made up of patent engineers, R&D personnel, and business managers. Samsung's local patent agents then draft the specifications and associated patent claims. Finally, the company files the applications both in Korea and other countries and regions that they deem important, such as the United States, Europe, and Japan.[76]

Standards engineers are always involved in this process. According to the standards experts from Samsung, LG and other firms that we interviewed, engineers who participate in standardization meetings often have to consult with lawyers about the details of specifications being discussed and possibly included in future standards. One interviewee goes further to say that the teams representing his firm at technical meetings often consists of at least one lawyer or patent engineer, who is responsible for intellectual-property issues that may arise in the meetings. It is commonly understood among technical experts that they should not reveal any proprietary invention and information during technical discussion in working groups. Yet, during participation in standards development activities, engineers may not be careful enough or may be tempted to unintentionally reveal the company's recent inventions.

Legal capabilities can be improved and sustained by recruiting new talents. Successful late standardizers, such as Samsung, realize the importance of having competent lawyers on its legal teams. Samsung has around 110 lawyers in 2005 and plans to increase the number to over 300 within 5 years. Similarly, Samsung aims to increase the number of patent experts from the current 250 to 450 by 2010. With its reputation and compensation structure, Samsung is able to attract the best legal talents.[77] This is an impressive pool of lawyers, considering that Kim & Jang, the biggest law firm in Korea, employs about 270 lawyers.[78] Samsung's plan to enlarge its legal team is driven by the need to enhance its legal ability to cope with the rapidly changing global economy and to strengthen its competitiveness by reducing legal risks.[79]

In fact, in February 2006, Samsung Electronics introduced a Chief Patent Officer (CPO) position in an attempt to reinforce the patent management within the firm. As Samsung is involved more in strategic alliances and large-scale patent conflicts, the patent management system with CPO has been established to cope with the changing environment in organized and consistent way. The CPO will take charge of the whole process of patent management from strategy planning and execution to professional training and patent quality improvement. The CPO will also coordinate different opinions from related divisions and deal with problems from external sources regarding intellectual property.[80]

THAI LATE STANDARDIZERS IN MOBILE TELECOM

The Thai domestic mobile telecom industry is characterized by oligopolistic competition between a few large service providers.[81] Unlike the Korean case, there are few, if any, Thai telecom equipment and handset manufacturers. This means the Thai government does not have as much incentive to nurture and develop domestic standards to support the domestic industry as in the cases of Korean and Chinese governments.

Our case studies focus on two of the most important mobile operators in Thailand: Advanced Info Service (AIS), the largest domestic mobile operator, and TOT, a former state-owned telecommunication firm which granted AIS a concession for mobile services.

From our empirical investigation, we find that latecomer firms in the mobile telecommunication industry in Thailand are in between the first and second stages of our late-standardization model. They are still far behind the successful Korean late standardizers, such as, Samsung, LG and KT, which have already entered the third stage of late standardization. The Thai firms have implemented various organizational quality standards and management, such as ISO-9000 series and Six Sigma. But their engagement in technological standardization is rather limited. In the following section, we discuss the late standardization efforts of these two firms.

ADVANCED INFO SERVICE (AIS)

Advanced Info Service (AIS) is Thailand's largest mobile service operator. In early 1990, the company was granted an exclusive 20-year concession by the Telephone Organization of Thailand (TOT) to provide mobile phone services using a 900 MHz system. AIS launched its first 900 MHz analog system services later that year. In 1994, AIS launched the Global System for Mobile Communication services. Later in 1996, AIS was granted an extension on the concession period from 20 years to 25 years by TOT, in exchange for a new agreement that TOT could also grant licenses to other operators besides AIS. AIS continued to expand its network for both the Cellular 900 and Digital GSM System to cover the whole country.

In 1999, AIS signed a business partnership agreement with Singapore Telecom International. In 2000, AIS improved its non-voice application services. Its mobileLIFE service enables subscribers to utilize a wide range of business applications with mobile phones. In 2000, AIS launched its GPRS (General Packet Radio Service) Technology, the service that facilitates hi-speed data transmission and connects mobile phone subscribers to the Internet. AIS also established its leadership in the domestic market by launching General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE). These are 2.5G protocols that support much higher data transfer rates than previous technologies. In early 2002, the company started to introduce the 3G technologies, although the varieties and ranges are still very limited.

From the above account, we see that AIS has constantly demonstrated its responsiveness in terms of technology applications. Yet, the company still has limited R&D capabilities. From our interviews with a vice president and a senior engineer, there are currently about 20 engineers working in its R&D division, the "Future Lab." Most of the activities, however, are in the development phase, rather than in the research phase. The Future Lab focuses primarily on adapting imported technologies to the domestic market. As customer satisfaction is the main goal of AIS' services, consumer preferences are the main criteria that often determine the directions of its technical-development effort. The development team focuses mainly on new services and applications that the firm can offer to the users. Currently, the firm holds about 2-3 domestic patents for the application technologies developed by AIS engineers.

Standardization efforts at AIS

As of April 2006, AIS is participating in at least three international standards development consortia. One is the GSM Association, a global trade association representing more than 690 GSM mobile phone operators around the world.[82] The other is the GSM User Group – Asia Pacific (GSMUG - AP) led by Ericsson. AIS is also a sector member in the ITU-D. The number of consortia that AIS participates has not changed in the past decade; AIS has been involved in both GSMA and GSMUG-AP since the early years of its operation. The company participates in a few domestic standards forums, such as Thailand IPv6 Forum.

AIS has limited involvement in standardization activities. Other than participating in the above consortia, the company has not participated in founding standards consortia, and has currently no plans to do so. This is not unexpected, considering that its current business strategies focus on technological applications and adoption, as well as its limited innovation and standards capabilities. Internally, the firm does not have a division or department devoted to standards activities. Most of the standards works are done by engineers in the Future Lab. They are involved in external standardization activities on an ad hoc basis. There are no specific guidelines or policies regarding standardization, although the company has a policy to review intellectual-property-right issues before joining a new standards forum.

In terms of sources of standards and related information, AIS relies mainly on its vendors, mostly European, such as Nokia and Ericsson. The selection of European vendors was determined greatly by the fact that AIS is a GSM-based operator. Engineers from AIS participate in forums for user groups organized by these vendors, and learn about new technologies and standards in such events. Because AIS do not participate directly in international standardization, it acquires information through the major vendors. For instance, AIS engineers learned about new ETSI standards proposals and approved standards for 3G technologies through GSMUG-AP forums, when representatives from Ericsson presented new technologies and applications. The firm also acquired some technical knowledge from its Singaporean business partner, SingTel.

AIS also receives technical support from the Thai government in terms of testing and calibration services. The firm expects the government to function as the contact point or clearing house for information on standards, particularly in the areas of safety and security.

From our interviews with the AIS employees, we have the impression that AIS is adopting a "follower" approach to standards-related issues. The AIS executives often mentioned the benefit of not having to "reinvent the wheel" by adopting vendors' standards and specifications. The AIS executives believed that, although standards issues are important, they are not the main focus of AIS' current corporate strategy. Rather, it is the role of the government to engage in international standardization and diffuse the information and knowledge to the private sector.

TOT

TOT was founded in 1954 as Telecommunication Organization of Thailand, a state enterprise under the Ministry of Transport and Communications. It was later transformed into a public company named TOT Corporation in 2002, and renamed to TOT in 2005.

Although TOT's main products were fixed-line services, the company entered the mobile phone market by offering mobile services based on the 470 MHz and 1900 MHz frequency ranges. TOT operates the 1900 MHz mobile service jointly with and CAT Telecom, another formerly state-owned firm, Communications Authority of Thailand (CAT). TOT plans to develop the 1900 MHz system into the 3G system.

TOT's standardization efforts

Because of its previous status as a state-owned telecommunication enterprise, TOT has been representing the country in various standardization activities at the international level. According to our interview with a TOT Vice President, TOT engineers have participated in meetings and conferences organized by formal standardization organizations and consortia. These organizations include the ITU, the Asia Pacific Telecommunity (APT), GSM Association, TeleManagement Forum (TMF), Internet Engineering Task Force (IETF), and IPv6 Forum. TOT also participates in a few local forums that exchange information on new technologies and standards, including Thailand-IPv6 Forum.

Compared to AIS, TOT is a larger organization, with more resources and capabilities devoted to R&D and standards activities. Approximately 200 TOT engineers work on various types of R&D projects. Many of its R&D activities, however, are limited to adapting and adjusting foreign technologies to local environmental and market conditions. Although TOT has sent its engineers to various standardization forums, its contribution to standards development is rather limited. The main objective of its involvement is to acquire information on new technologies and standards.

TOT also acquires information and knowledge on new standards and technologies through its major vendors, such as NEC, Ericsson, Siemens, and Cisco. Lately, TOT has become more interested in Chinese manufacturers, such as Huawei Technologies and ZTE. TOT has recently bought Huawei's equipment as part of its plan to expand its network for broadband data backbone transmission.[83] Although Huawei is not yet a world technology leader, the firm has made significant progress technologically due to its aggressive investment in R&D. According to the TOT vice president, TOT has purchased the equipment from Huawei, not only because of its low prices compared to other vendors, but also because of its technical reliability and support. Considering that the Chinese firm is engaging actively in international standardization, they could be another source of information and knowledge on standards and standardization for TOT.

In summary, latecomers in the mobile telecom sector in Thailand are still far behind the successful Korean late standardizers, in terms of level of contribution to, and influence on, international standardization. They still rely on foreign vendors that are standards leaders for information and knowledge related to standardization. Our interviewees all agree that the state should play a more active role in standardization activities.

TELECOMMUNICATION STANDARDIZATION IN THAILAND

Various governmental agencies are in charge of telecommunication standardization in Thailand, including the Telecommunication Standard Division in the Post and Telegraph Department under the Ministry of Information and Communication Technology and the Thai Industrial Standards Institute (TISI). In addition, because of their former status as state-owned telecommunication enterprises, TOT and CAT are involved in certain aspects of telecom standardization, particularly in testing and calibrating telecom equipment and products.

Another agency that has become active in technical standardization in Thailand is the National Electronics and Computer Technology Center (NECTEC). Researchers from NECTEC represent the country in several standards meetings, both in formal SDOs and industry consortia. NECTEC also hosts a few domestic consortia, in which researchers and the private sector exchange information on new standards and technologies.

CONCLUDING REMARKS

The case studies of latecomer firms in the semiconductor and mobile telecommunication industries demonstrate how standards and related activities enable latecomer firms to improve their competitive positions. Quality standards and standardization are the first step for latecomer firms to move up the ladder of competitive advantage. Then, latecomer firms may become the leader in a market segment, in terms of market share, without being a standards-leader. But it has to join standards-development clubs to upgrade its competitive positions. The types of standards organizations and forums in which latecomer firms participate are also related to their levels of technological and standards capability.

Late standardizers' emergence as a leader in certain industry is generally first manifested through market share, then through technological breakthrough, finally through the influence on technical standardization. The focus on quality standards and management is the first step for late standardizers to move beyond catch-up. As they move closer to the world technological frontier, external standardization activities become a key factor that affects their strategy and competitiveness. Our case studies suggest that standards and standardization are at the heart of these firms' R&D strategies and their competitive advantage.

These successful late standardizers also adjust their internal organizational structures, such that standards activities become a core component of R&D strategies and policies. Human resources policies need to accommodate the career growth of standards engineers, such that they are continuously involved in standards activities.

CHAPTER SEVEN

THE STATE'S ROLE IN LATE STANDARDIZATION

PROVIDING INFRATECHNOLOGIES FOR QUALITY CONTROL ■

ESTABLISHING STANDARDS INSTITUTIONS ■ PROMOTING NETWORKING ■

MITIGATING TECHNOLOGY AND MARKET RISKS ■ STANDARDS DIPLOMACY FOR OVERSEAS MARKET EXPANSION ■ PROTECTING INTELLECTUAL PROPERTY ■

CONCLUDING REMARKS

Through the case study of the Korean government and standards institutions, we find that the state plays a critical role throughout the process of late standardization and technological catch-up. Yet, the nature of the involvement changes as latecomer firms gain more technological capabilities and move closer to the technological frontier. As late standardizers enhance their technological capabilities, the sources from which they capture economic rents change from cheap input factors to production capabilities then to innovation capabilities. During such a process, the state adjusts its roles from being the main developer and enforcer of standards to become a mediator and coordinator of standardization efforts both domestically and internationally. The main goal is to help late standardizers improve internal standards capabilities, so that they can leverage external resources through linking and learning.

As late-standardizing firms move from the positions of late adopters to fast followers, and eventually to technology and standards leaders, the state implements various standards policies and programs so that firms can capture greater technological rents. The state plays significant roles in six key ways: (1) supplying basic standards as infratechnologies, (2) securing demand by mitigating market risks, (3) promoting knowledge diffusion through facilitating networking, (4) reducing technology risks through technology search and forecast, (5) lobbying and negotiating with other states for market expansion of domestic standards, and (6) establishing institutional and legal frameworks to protect intellectual property.

As part of the supply-side standards policy, the state provides firms with "infratechnologies," such as basic and reference standards, throughout the late-standardization process. These infratechnologies are the basis for industrial standardization and quality control, which are the main elements that allow latecomers to move beyond catch-up. The Korean state has regarded quality standardization and control as an essential part of its export-oriented industrial policy since its early years of industrialization. During the catch-up stage, the state not only searches for and/or develops standards but also maintains, and diffuses standards for latecomer firms. Experts from state agencies participate in international standardization. The state assumes the leading role not only in the field of non-product standards but also product-element standards, especially in the areas of infratechnologies and generic technologies that lead to market applications in the forms of products and services.

Infratechnologies are generally beyond the financial and technological capabilities of individual latecomers. They have strong public-goods characteristics, resulting in under-provision by the market. The state hence assumes the prime role in producing and providing infratechnologies from the early stages of late standardization. Throughout the late-standardization process, particularly during the catch-up stage, infratechnologies are essential to latecomers' efforts in quality management and standardization. Even at the stage where late standardizers are already at the technological frontier, the state remains crucial in providing even more sophisticated infratechnologies for firms.

As part of the demand-side standards policy, the state plays an important role in mitigating initial market risks associated with new standards. The state may be able to do so by declaring or mandating certain standards as national standards, by becoming a first and a model user through public procurement policies, and/or by protecting the domestic market through protectionist trade and industrial policies. Before standards are developed, prices are often determined by product value. Once standards are developed and products are standardized, prices are determined by costs. Through case studies of South Korean standards institutions, we observe how the state uses different policies and programs to increase the value for the targeted technologies. The state may also mitigate the risks associated with market creation by cooperating with other countries to adopt the same standards. This "standards diplomacy" effectively creates a regional bloc based on common technical standards. Korea's cooperation in standardization with Japan and China is the case in point. The Korean state has recently pursued active standards diplomacy in order to expand its export markets in Asia.

The state plays another important role in reducing technology risks associated with selecting the right technologies and standards. By supporting R&D activities conducted by research and educational institutes, the state could reduce the technology risks that firms face by searching and identifying which technologies and standards to be adopted. As late standardizers move closer to the world technological frontier, the state plays a more critical role by identifying and predicting the future trends of standards and technologies.

The state can also facilitate information and knowledge flows between firms, especially when late-standardizing firms have limited search capability. State-led networking is crucial to standardization at the domestic and international levels. Even though consortia increasingly become important for standardization of new technologies, formal standards organizations, such as the ITU and the ISO, are still the major forums for international standardization. In these forums, late-standardizing states, such as the Korean government, still participate as the member body. The state remains active in deciding the directions and strategies of standardization. It retains its role as the representative negotiator on behalf of latecomer firms.

In this chapter, we discuss the roles of the state in the process of late standardization, based on the empirical evidence of the Korean government and standards institutions. We first pay attention to the roles of the state in providing standards as infratechnologies. Our focus is on the standards policies and programs for improving product quality and quality management. We then turn our attention to the role of the state in establishing standards institutions, focusing on its role in developing and enhancing national systems for measurement and documentary standards. Then we discuss the role the state in mitigating technology and market risks. We then discuss "standards diplomacy," in which the Korean state has been particularly active in recent years. This is followed by its role in protecting intellectual property rights related to standards. We use the case of the Korean state in the mobile telecommunication industry to examine such roles. Throughout the chapter, we illustrate the changes in the roles of the state, as late standardizers move towards and beyond technological frontier. Specially, we examine what standards activities and responsibilities the state assumes and focuses on in each stage of the late-standardization process.

PROVIDING INFRATECHNOLOGIES FOR QUALITY CONTROL

Throughout the late-standardization process, the state plays an important role in providing firms with standards that are "infratechnologies," such as basic and reference standards. Infratechnologies are the basis for quality management and control, which in turn is the foundation for manufacturing and innovation capabilities. Latecomer firms can use infratechnologies as the basis for their efforts to enhance product quality and to improve quality control and management throughout their late-standardization process.

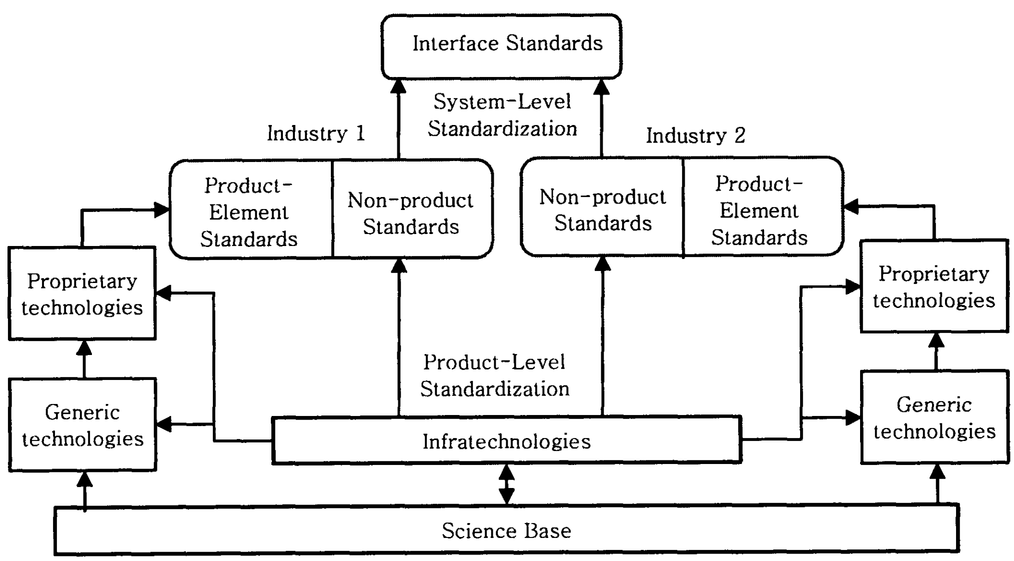
STANDARDS AS INFRATECHNOLOGIES

Basic and reference standards are infratechnologies, which are technical tools that include scientific and engineering data, measurement and test methods, and practices and techniques for wide industrial application. Infratechnologies are critical to the development of generic technologies and subsequent proprietary technologies, which in turn are developed into market applications in the forms of products and services (Figure 7.1). Infratechnologies often appear as non-product standards, which form a basis for a whole product or service. Non-product standards are usually competitively neutral within an industry. By contrast, product-element standards involve one or a few attributes of a product, and create direct competitive advantage for the owner of the technology underlying such attributes (Tassey 2000).

Infratechnologies play an important role in technological development in at least three important ways (Tassey 1997). First, infratechnologies increase production efficiency and enhance product characteristics by providing tools for quality control and management, as well as real-time process control. As we argue in previous chapters, internal quality standardization and management is the key factor that enables latecomers to move beyond catch-up. Infratechnologies in the forms of measurement standards and reference materials are thus the essential element of technological catch-up and beyond.

Second, infratechnologies promote technology adoption by reducing transactions costs. Infratechnologies increase the speed of market penetration by providing a language for communicating the characteristics and quality of a new product, process, or service. Third, infratechnologies increase R&D efficiency. With common measurement technologies, test methods, technical standards, and standard practices, researchers are able to conduct and exchange R&D results, which allow for the replication and verification of research results.

Figure 7.1: Standards as Infratechnologies



Source: Adapted from Tassey (1997) Figures 1 and 3

As discussed in Chapter Two, standards have public-goods characteristics. This means standards as infratechnologies are generally underprovided by private markets, as compared to the socially optimal levels of provision. The private sector may under-invest in infratechnologies, because its technology base is different from the core technology that industry draws on to develop its product or processes (Tassey 1997). This is especially true for non-product standards, which are developed from different scientific and technical bases from those of product-element standards. Non-product standards, such as measurement and test methods, and interface standards, demonstrate the current, most-accurate statement of the fundamental laws of physics (Tassey 1982). The state thus normally assumes the role to provide these basic standards to correct the perceived market failure.

The involvement of the state is not limited to non-product standards, but often includes product-element standards. If large economies of scale are present or early market entry is regarded crucial to national economic development, the state may directly specify product-element standards (Tassey 2000). This is, in fact, the main rationale and focus of the Korean government in its involvement in recent standardization efforts in the ICT sector.

From our case study of South Korea, we find that the roles of the state remain crucial throughout the late-standardization process. Yet, the roles of the state change as late standardizing firms enhance technology and standards capabilities. As latecomer firms develop closer to the world technology frontier, they rely less on the state for the development and provision of product-element standards. Particularly, advanced late standardizers at the forefront of the technological frontier become more active and influential in both domestic and international standardization activities. The increased direct involvement of the private sector and the decreased role of the state may be explained by the interactions between the following three factors: (1) technological distance of standards from the frontier, (2) public-goods characteristics of standards, and (2) appropriability of rents generated by standards.

Traditionally, formal standardization organizations develop “reactionary standards” to standardize technical features that have been implemented by firms. One major objective is that standards generate benefits that firms and consumers can all enjoy, as in the case of public goods. Most national standards organizations are pubic agencies. However, the processes tend to be time-consuming; the technologies often become mature by the time the standards are developed. However, many critical standards in fast-changing fields, such as information technology, are increasingly developed by standards consortia when the technologies are relatively new. These “anticipatory standards” define the technical features that firms later adopt. This means the technological distance of the technologies embedded in the standards are closer to the frontier. As the technologies underlying standards tend to be proprietary to firms, there are clear incentives for firms to adopt standards strategies that allow them to appropriate the rents induced by standards. Instead of relying on the state to develop standards as before, firms opt to develop standards by themselves, preventing the “club goods” from becoming “public goods”.

This does not mean, however, that the state plays less important roles regarding standards and standardization. Basic and reference standards remain important for R&D and quality control and management, regardless of how technologically advanced the private sector is. Because these standards are infratechnologies, the state still plays the major role in providing them. Furthermore, institutional arrangements affect how firms adopt standards strategies and activities. We now turn our attention to the role of the state in setting up standards institutions.

ESTABLISHING STANDARDS INSTITUTIONS

Throughout the process of late standardization and technological catch-up, the state is the main actor that sets up and maintains the institutional framework for standards activities. Standards institutions include not only the organizations that deal with standards activities but the policy and legal frameworks that shape the standards systems. One can think of a country's institutional arrangements for standards activities in terms of a national standards system. In most countries, the central governments are responsible for setting up and maintaining the national standards systems.

NATIONAL STANDARDS SYSTEMS

A national standards system (NSS) includes not only standard-setting organizations, but includes product-testing laboratories, certification and accreditation bodies, which operate within certain policy and legal frameworks designed specifically for standards activities. These institutions constitute important technological infrastructure that supports technological capability building. The national system for product and process standards is a critical element of a national production and innovation system. The sophistication and performance of a national standards system is, in fact, an indicator of technological and innovation capability of a country. The adequacy of these standard institutions not only raises the actual quality of domestic products and processes, but also improves the perception and confidence on the quality of local products and processes in the domestic and international markets.

A national standards system is thus a system in which different entities within a nation develop and utilize objective criteria to comprehend and solve commonly existing, recurring, or new technical problems within certain policy and legal institutions. Because standards systems function as a medium for technological transfer across space and time, they serve as the basis for ensuring the quality and performance of industrial goods and economic transactions. At the national level, the development of sophisticated standards systems goes hand-in-hand with the development of production and innovation systems. The ability to set and assess standards is thus closely related to technological capability, and standards facilities are an important element of production and innovation systems.

Legal foundation for standards activities

A well-functioning national standards system operates within legal frameworks designed specifically for standards activities. This is the case for the Korean national standards system. As shown in Table 7.1, since the beginning of its modern standardization in the early 1960s, the Korean state has enacted several legislations for standards activities. Major legislations include the Industrial Standardization Act (1961) and the Weights and Measures Act (1961), the Export Goods Inspection Act (1962), and the Industrial Product Quality Control Act (1967). Under these legislations, relevant standards organizations were established as part of the national measurement and documentary standards systems. Since then, some of the legislations have been revised and new legislations have been added to the standards system. This reflects the changes in the nature of standards and standardization activities, as well as the changing roles of the state.

Table 7.1: The Korean State's Standards Activities in the Late Standardization Process

Stage and Time Period	Major Characteristics	Domestic Activities	International Activities	Major Legislations	Institutions
Pre-catch-up: Before 1960	State control of standards	Standardization of physical infrastructure (e.g., rail gauges) Basic industrial measurement and standardization	Limited (e.g., postal and telephone, telegraph)		Analysis and Testing Laboratory of the Mint Office (1883) → Central Testing Institute under the Ministry of Agriculture, Commerce and Industry (1912) → Central Industrial Research Institute under the Ministry of Trade and Industry (1945) →
Catch-up: 1960s	State-led formation of modern national standards system	Establish institutional and legal frameworks for standardization Establish national measurement and documentary standards institutions Legal metrology Basic industrial standardization Marking certification	Represent the country in formal standardization Limited involvement in consortium-based standardization	Industrial Standardization Act (1961) Weights and Measures Act (1961) Export Goods Inspection Act (1962) Industrial Product Quality Control Act (1967)	Bureau of Weights and Measures under Ministry of Trade and Industry National Industrial Research Institute (1962) to inspect quality of export products
1970s	State-led expansion of national standards system	Conformity assessment, certification Establish and disseminate metrology standards and support quality control and industrial standardization Improve the quality of industrial products and protect consumers		Industrial Advancement Administration (1973) under Ministry of Trade and Industry	→ National Industrial Standards Testing Institute under the Industrial Advancement Administration (IAA) (1973) → National Industrial Testing Institute under the IAA (1976) →
Keep-up: 1980s	Public-private partnership	Continued focus on quality standards State-led standards activities, but increased contribution by the private sector	Mainly government representation in both formal and informal forums	Civil Law, Article 32 (for TTA establishment)	More industry associations with state support; R&D institutions.
Late 1980s-early 1990s		Increased use of international standards		Framework Act on Telecommunications (1992) (TTA reincorporated under Article 30)	Telecommunications Technology Association (1988) Communication Technology Promotion Council (1988)
Forge-ahead: Late 1990s-present	Private sector-led standardization	Provide forums for private firms to discuss standardization Private firms offer metrology and conformity assessment services, except for the most advanced measurement R&D support for standards IPR Enforcement	More industry representation in both formal SDOs and consortia	National Standards Act (1999)	→ National Industrial Technology Institute under the Industrial Advancement Administration (1991) → National Institute of Technology and Quality under the Small and Medium Business Administration (1996) → Korean Agency for Technology and Standards (KATS) under the Ministry of Commerce, Industry and Energy (1999)

The most fundamental feature of the Korean national standards system is its constitutional basis. Article 127 of the Korean Constitution specifies the role of the state in developing science, technology, and innovation. Within the same article, there is a specific paragraph indicating the role of the state in establishing a national standards system:

> (1) The State shall strive to develop the national economy by developing science and technology, information and human resources and encouraging innovation.
>
> (2) The State shall establish a system of national standards.
>
> (3) The President may establish advisory organizations necessary to achieve the purpose referred to in paragraph (1) [84]

The provision on standardization was added to the Constitution on October 27, 1980, when the constitution was amended.[85] Although many countries have provisions related to standards in their constitutions, most focus on standards of weights and measures. Building on a table reported by Kim (1986), we compile Table 7.2 to show the standards provisions in the constitutions of select developed and developing nations. We find that many developed countries have provisions regarding weights and measures in their constitutions. In contrast, very few latecomer countries have such provisions in their constitutions, even though some of them, such as Thailand, explicitly indicate the importance of science and technology.

The Korean constitution is particularly unique. It does not provide an explicit statement on weights and measures per se; rather it calls for an establishment of the national standards system. This is certainly more comprehensive, because it includes areas of standards and standardization other than weights and measures. As noted by Kim (1986), many developing countries stipulate the promotion of science and technology without stipulating any provisions for national standards. This indicates the lack of understanding about the fundamental role of standards in technological and economic development.

Table 7.2: Standards-Related Provisions in Constitutions in Select Countries

Country	Article	Content
U.K. (Magna Carta)	Section 35	There shall be one measure of wine throughout our whole realm, and one measure of ale and one measure of corn--namely, the London quart;--and one width of dyed and russet and hauberk cloths--namely, two ells below the selvage. And with weights, moreover, it shall be as with measures.
U.S.A.	Article 1-8	The Congress shall have Power...To...fix the Standard of Weights and Measures
Germany	Article 73	The Federation has the exclusive power to legislate on: ...weights and measures, as well as computation of time
Switzerland	Article 125	Legislation on weights and measures is a federal matter.
Austria	Article 10-1	The Federation has powers of legislation and execution in the following matters: 5. ...the weights and measures, standards, and hallmark system;
Canada	Article 91	the exclusive Legislative Authority of the Parliament of Canada extends to ... Weights and measures
Taiwan	Article 107	The Central Government shall be competent to legislate and execute the following matters: ...Weights and measures
Brazil	Article 22-VI	It is incumbent exclusively upon the Union to legislate on ...measures system
Mexico	Article 73-18	The Congress has the power...to adopt a general system of weights and measures
South Africa	Section 44-2	Parliament may intervene by passing legislation ... to maintain essential national standards
South Korea	Article 127-2	The State shall establish a system of national standards.

Sources: Adapted from Table 58 in Kim (1986) with additional and updated information from International Constitutional Law Project Information at website: http://www.oefre.unibe.ch/law/icl/info.html, accessed in April 2006.

The standards provision became part of the Korean constitution during the time when the country was drafting a new constitution to replace the so-called Yushin Constitution.[86] The National Assembly Committee on Constitutional Amendment was calling for public proposals to gather inputs for the new constitution. Responding to that request, Dr. Zae-Quan Kim, the then President of the Korea Standards Research Institute (KSRI) submitted a proposal, suggesting that the new constitution include a clause on the establishment of a national standards system. This proposal was well received by the government and the National Assembly. After maneuvering through political hurdles and several revisions, the proponents of the standards clause managed to have it included in the new Korean Constitution, which was confirmed by the national referendum on October 27, 1980. (Kim 1986)

The constitutional provision for the national standards system has important implications for the late standardization processes of Korean latecomers. The concept of national standards system in the constitution is much broader than merely having laws for standards of weights and measures and/or for industrial standardization. It specifies the fundamental and holistic characteristics of standards activities.

KOREAN NATIONAL STANDARDS SYSTEMS

In general, a national standards system is categorized broadly into two sub-systems, that is, national measurement system and documentary standards system. The national measurement system comprises activities and institutions dealing with measurement and reference standards. On the other hand, the national documentary standards system deals with legal metrology and documentary standards, which deal with industrial specifications as well as health, safety, and environmental regulations. Each sub-system is further categorized into two main activities: standardization and conformity assessment.

As defined earlier in Chapter Two, standardization is the process by which standards are developed and recorded. Conformity assessment, on the other hand, refers to activities of complying with standards, such as product testing, product certification and quality system registration. Although conformity assessment is not a standard per se, it is a critical part of standards efforts. Firms not only have to comply with standards but have to verify that their products and processes meet such standards. Conformity assessment not only depends on the existence of clear standards, but also affects the value of standards by increasing the confidence that firms and consumers have on standards. Conformity assessment is especially important in international trade, as credible certification and accreditation systems can demonstrate the quality of the traded products.

Conformity assessment is possible at three different levels (National Research Council 1995). First, *assessment* ability refers to the evaluation of products and processes, which can be done by manufacturers, testing laboratories, certifiers, or quality system registrars. These entities are also evaluated to make sure they are competent in conducting specific tests using specified methods. This second level of conformity assessment is referred to as *accreditation*. The third level of assessment is *recognition*, in which accreditors are evaluated. The activities at the three levels necessarily require active participation of both the pubic and private sectors.

National measurement standards system

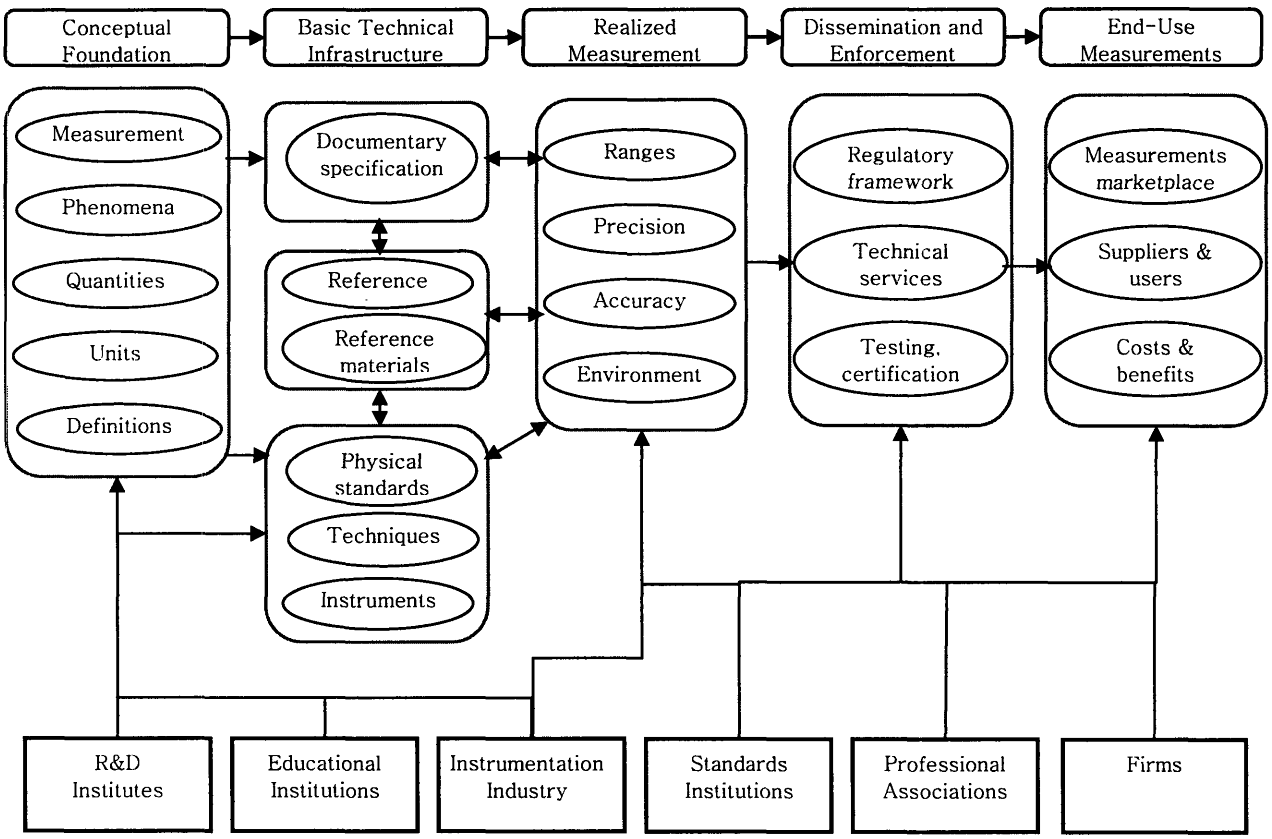
A large component of a national measurement standards system is metrological activities. Specifically, metrology includes theoretical and practical problems related to measurement units, measuring instruments, methods and execution of measurement, and estimation of their characteristics (ISO 1987). A measurement standard could be a material measure, a measuring instrument, a reference material, or a measuring system, which is intended to define realize, conserve or reproduce a unit or one or more values of quantity to serve as a reference. Metrology is a critical component of technological infrastructure, as it is the foundation of a quality system. Transactions of goods in both domestic and international markets rely on accurate measurement.[87] The overall capability to measure, test, calibrate, and certify products and processes, as well as to develop and maintain standards, are important elements of technological capability (Hawkins et al. 1995).

A reference standard is the data and information on measurements made available to the public, with the accuracy and reliability that has been obtained through scientific analysis and evaluation. Reference standards include physical constants, recognized property valued and scientific and technology data. As science and technology develop, more data and information on the property of a substance or system of substances become necessary. These data and information could be distributed uniformly and reliably through reference standards.

Reference standards are important for industrial and technological development in various ways. Not only do they facilitate the design and production of industrial goods, but they also promote product quality and provide the basis for environmental control and other services. A national measurement system comprises activities and institutions dealing with measurement and reference standards. Figure 7.2 shows an example of a national measurement system, based on the model proposed by the U.S. National Bureau of Standards (now NIST).

The state's presence in a national measurement system is strengthened by its direct control over legal metrology. Legal metrology deals with legal requirements for establishing, reproducing, conserving, and disseminating measurement units, as well as for examining and verifying measuring instruments (ISO 1987).

Figure 7.2: An Example of a National Measurement Standards System



Source: Adapted from NBS (1975)

Korean standards systems: the focus on quality improvement and control

The Korean state has played an important role throughout the late-standardization process of latecomer firms. Yet, the focus of its standards policy and programs are different in each of the three stages of late standardization. During the early stages, the Korean state focused its standards activities mainly on two aspects, that is, the development of measurement standards system and the industrial standardization for export-oriented industrial development. By engaging directly in industrial standardization, the state aimed to achieve various goals, including consumer protection in terms of safety and health. However, the most important objective was to enhance the quality of industrial manufacturing by Korean firms. The development of national standards systems was an essential element of Korea's export-promotion policy and a crucial part of its broader goal to industrialize the economy. The focus on quality improvement was reflected in the enactment of the Industrial Product Quality Control Act (1967), while the focus on quality for export products was reflected in the Export Goods Inspection Act (1962). As part of the development, the government implemented several standards policies and programs and established various institutions devoted to standards development, enforcement, and R&D.

As a number of Korean firms increase production and innovation capabilities, the Korean state shifts its attention to strategic standardization for product elements. As shown in Table 7.1, the nature of standards activities implemented by the Korean state evolves, which we discuss in detail below. The main feature of the strategy is to increase institutional complementarities between domestic and international institutions. Specifically, the Korean state has changed its domestic standards institutions in such a way that Korean firms enjoy the externalities generated from international standardization.

Korean measurement standards system: the basis for quality improvement

An essential element of any national standards system is the measurement standards and legal metrology systems. Measurement standards are the cornerstone of quality control and management, the basis for industrial development. In Korea, some forms of measurement and reference standards were available before the nation embarked on its modern industrialization efforts in the early 1960s. The Korean state established institutions for basic measurement standards, including the Analysis and Testing Laboratory of the Mint Office (1883), the Central Testing Institute under the Ministry of Agriculture, Commerce and Industry (1912), and the Central Industrial Research Institute under the Ministry of Trade and Industry (1945).

However, it was not until the early 1960s that the modern measurement standards system started to take shape. The Korean state started to recognize the importance of modern standards system at the national scale as part of its industrial-development efforts. This recognition was evident in the first and second economic development plans (1962-1966 and 1967-1971). When South Korea entered the stage of heavy and chemical industrialization in the 1970s, the importance of standards became even more pronounced (Kim 1986).

The first modern legislation for the Korean national measurement system was the Weights and Measures Act in 1961. The Act was later revised in 1992, and now includes a broad range of technical areas, such as specification of legal units for measuring physical quantities, national calibration system, and provisions for establishing a national accreditation system for testing/inspection laboratories. The Ministry of Commerce, Industry and Energy (MOCIE) maintains the Act, and is responsible for establishing related policies and programs. The actual responsibilities for administering metrological policies, however, are entrusted to the Korean Agency for Technology and Standards (KATS), previously known as the Korean National Institute of Technology and Quality (KNITQ). The Weights and Measures Act and the Industrial Standardization Act were effectively the major tool that provided the Korean government with the control on the quality of industrial products produced and sold in the country. Under the Weights and Measures Act, KATS manages the legal metrology system in Korea, and coordinates the national calibration system for measurement instruments. KATS is also the national standardizing body for industrial standards (KS standards), and represents Korea as the national member body in the ISO and the IEC.

Standards capability

The state's standards capability affects firms' standards capabilities. Standards capability is simply defined as the capability of an actor (individual, firm, or institution) to deal with standards (Vries 1999). At the firm level, standards capabilities generally include the capability to identify the needs for standards, to search for and select appropriate standards, to acquire and assimilate standards into the production process, to adapt standards to local conditions, to modify standards in response to changing economic conditions, and to develop new standards for internal and external uses. In addition to these capabilities, the state's standards capability includes the capability to develop national standards, to disseminate such standards to the private sector, and to represent the country in international standardization forums. The state may also play an important role in tracing relevant standards, especially for firms that have limited resources and capabilities for standards activities.

Standards capability is not merely a technical capability to develop standards and technical specifications, but include institutional and organizational capabilities. Standardization involves more than technical exchanges among engineers. It includes political maneuvering and negotiation among participating parties. As demonstrated in the study of the International Telecommunications Union (ITU) by Krasner (1991), the participating states often lobby to have the technical preferences of their firms be included in international standards. Even when the states are not directly involved in the actual technical standardization and delegate the task to the private sector, they can still exert influence on the private sector to reflect the interests of the states in standardization.[88] The state's standards capability is thus an important indicator of the capability level of a national standards system.

Despite the enacted laws and the established institutions, the overall measurement capabilities in Korea did not develop fast enough to accommodate the needs of the growing modern industries in the country in 1960s and 1970s. The government responded by increasing its effort in improving measurement standards capability by establishing R&D and testing labs devoted to measurement and reference standards. (Kim 1986)

An indicator for measurement capability is the so-called realized measurement capability, which is the accuracy with which an element is measured. Korea's realized measurement capabilities have improved significantly in the past 40 years (Table 7.3). Even though its overall capabilities still lag behind the United States., its capabilities are much more advanced that those of Thailand in 2004.

Table 7.3: Realized Measurement Capabilities of South Korea

	Unit	Accuracy (1985)	Accuracy (2004)	Cf. US (2004)	Cf. Thailand (2004)
Length	m	10^{-8}	10^{-9}	0.05×10^{-9}	0.7×10^{-6}
Mass	kg	10^{-7}	2.8×10^{-7}	2.4×10^{-7}	n.a.
Frequency	Hz	10^{-12}	2×10^{-13}	2×10^{-13}	n.a.
Electricity (DC)	V	10^{-6}	0.5×10^{-6}	0.14×10^{-6}	0.5×10^{-6}
Temperature	K	5×10^{-3}	4×10^{-3}	0.15×10^{-3}	3×10^{-3}
Luminous Intensity	cd	2×10^{-2}%	3×10^{-2}%	1.5-0.5 10^{-2}%	n.a.

Note: South Korea's accuracy figures are based on those maintained at Korea Research Institute of Standards and Science(KRISS). US accuracy figures are those of National Bureau of Standards (NBS), now the National Institute of Standards and Technology (NIST). Thailand's accuracy figures are from the National Institute of Metrology of Thailand (NIMT). n.a. = data not available.

Sources: Kim (1986), NIMT (2004), NIST Technology Services website at: ts.nist.gov, Bureau International des Poids et Mesures (BIPM) website: www.bipm.org

National documentary standards system

The other main component of a national standards system is the documentary standards system. A documentary standards system generally involves industrial standardization, which produces documentary specifications and codes, including terminology, symbols, and signs. Documentary standards are technical documents that describe technical characteristics of products, processes, services, or systems. As with measurement standards systems, documentary standards systems comprise two main activities, namely, standardization and conformity assessment. Generally a core component of a national documentary system is a national standards body, which oversees industrial standardization activities. Some national standards bodies may also be in charge of conformity assessment activities, particularly those in developing countries where standards capability is limited and the state assumes most of the standards-related activities.

Industrial standardization is conducted either by the government, the private sector, or both. The institutional arrangements for industrial standardization vary, according the political, economic, cultural, and legal characteristics of each country. In the United States., for instance, the private sector, led by the American National Standards Institute (ANSI), takes charge of industrial standardization in all industrial sectors. The federal government, through the work of NIST, assumes supportive roles by conducting research and diffusing knowledge on non-product-element standards that are infratechnologies (Tassey 2000). In our case study, the Korean state has continuously played a leading role in industrial standardization and conformity assessment. Not only did it set up the institutional framework for standards activities, but the Korean state has also assumed an active and direct role in developing and diffusing both measurement and documentary standards. The main focus is always on quality improvement.

Documentary standards systems to promote and control product quality

Another important component of the Korean state's involvement in standardization is in the development of national documentary standards system. The comprehensive modern standardization system in Korea started in 1961 when the Industrial Standardization Act was enacted. It was the first time a consensus-based standards development system was introduced to Korea. With this Act, the Bureau of Standards was established under the Ministry of Commerce and Industry. The role of the Bureau of Standards was to establish Korean Industrial Standards (KS) through the Industrial Standards Committee. Meanwhile, a voluntary product certification scheme was adopted for the KS system. The Bureau of Standards was authorized to issue "licenses" to manufacturers that demonstrated the ability to produce products that conform to relevant KS and licensing criteria.

The importance of the export markets was well recognized by the Korean government at the early stage of the country's late standardization process. Indeed, the export market was the key target for the development and enforcement of standards. The Korean government enacted and enforced the Export Product Inspection Act as early as 1962. Under the Act, the National Industrial Research Institute (NIRI) was established, with the mission to inspect export products so as to assure and improve the quality and credibility of Korean products in international markets. Meanwhile, the Fine Instrument Center (FIC) was established to inspect and assure the quality of electrical and electronic products.

Although the five-year economic-development plans have always incorporated some import-substitution components, export markets were the main target for the Korean industrial efforts. By developing national standards systems, the government aimed to improve the quality of industrial products and the uniformity of their quality, such that the Korean products gained reputation and credibility in the export markets. One important element of this effort is the development of the Korean Standards system.

The Korean Standards and the "licensing" system contributed significantly to the development of Korean industries in its early industrialization periods in the 1960s and 1970s. The development of industrial standards systems in Korea comprised the establishment of several standards institutions, covering various aspects of industrial standardization.

One important institution established in 1962 under the Industrial Standardization Act was the Korean Standards Association (KSA). KSA is a non-profit institution aimed to improve the quality of the industrial products and service through the implementation of industrial standardization and quality improvement. KSA provides education and training in the fields of quality management and control, and quality standardization. KSA is also undertaking the job of secretariat of Korean Government for national quality promotion activity and has responsibility on administration of Korean National Quality Management Award.

Korean industrial standards (KS)

Korean Industrial Standards (KS) is a national standard system, which is deliberated by Industrial Standard Deliberate Council under the Industrial Standardization Act and officially approved by the administrator of Korean Agency for Technology and Standards (KATS). KS consists of sixteen categories and is divided into three parts, including:

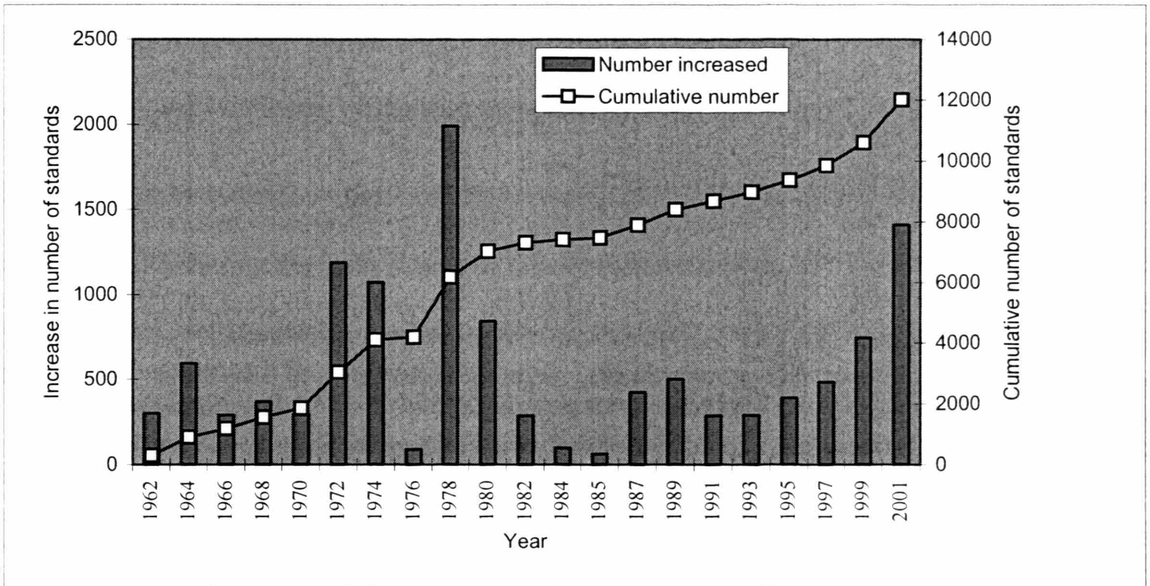
- Product standards specifying improvement, dimensions, quality of products;
- Method standards, specifying test, analysis, inspection and measuring methods, work standards; and
- Communication standards for terminology, technology, units, progression.

The KS system comprises two sub-systems: the KS Standard Maintenance System and KS Marking Sub-system. Standards are developed, updated, reaffirmed, and withdrawn within the KS Standards Maintenance system. On the other hand, under the Marking System, the government grants firms the permission to use the KS marks on the product or production techniques, provided that they meet the requirement on quality levels and quality management required by KS. KATS is responsible for establishing the KS standards and operating the KS Marking System. Until 1998, KATS had also handled the KS marking certification. The certification was known as the KS Marking Permit for domestic manufacturers and the KS Marking Approval for foreign manufacturers. Currently, the private sector handles all certification work, which is known as the KS Marking Certification (Choe 2003).

The KS Marking System contributed significantly to the improvement in quality and quality management for Korean industrial products As Figure 7.3 shows, the number of Korean Standards has continuously increased in the past four decades. Particularly, since the late 1990s, the number has increased significantly. Both the Korean government and the domestic industry started to recognize the importance of standards and standardization, putting more efforts and resources into standards activities. As part of the effort, KATS undertook a program, from 2000 through 2005, to make Korean standards consistent with international standards.[89]

Several agencies were also established to deal with conformity assessment, including the National Industrial Standards Testing Institute in 1973 and the National Industrial Testing Institute in 1976 both under the Industrial Advancement Administration (IAA).

Figure 7.3: Number of Korean Industrial Standards (KS), 1962-2001



Quality Management Convention and Quality Management Awards

Both the Korean government and the private sector have long committed to quality and quality management. One indication of such commitment is shown every year at the National Quality Management Convention, organized by the Ministry of Commerce, Industry, and Energy (MOCIE) and the Korean Standards Association (KSA). The main objective of the convention is diffuse knowledge and other positive effects of quality management to the Korean industry. Several sessions are held during the convention to present cases of quality management and innovation and to confer awards to firms and individuals who have contributed to quality improvement in the Korean industry.

The fact that this convention has been held every year since 1975 shows the long-term commitment of the Korean government and the private sector to quality standardization and control. By 2004, the awards had been given to 332 excellent quality management corporations, 2,503 excellent decisions, 1,033 quality management masters, 43 proposal makers, and other 1,107 dignitaries.[90] More than 1,400 people participated in the 30th Convention in 2004, representing governmental agencies, research and educational institutions, and enterprises from all industries.[91]

Q-Korea Initiative

A number of Korean late standardizers, such as Samsung and LG, have significantly improved their manufacturing capabilities and quality management up to the world standards. Yet, many of the successful firms are Chaebol-affiliated firms, while non-Chaebol firms generally lag behind. In addition, quality management activities have been operated separately by each firm without much co-operation among them.

To alleviate these problems and to upgrade Korea's innovative quality management, the Korean government through the KSA started the "Q-Korea" campaign in 2004. The major components of the Q-Korea initiative includes: (1) Q-Net, a information network; (2) Q-119, a cooperation of major Chaebols that diagnoses quality management problems and provides solutions to members; and (3) Q-Forum for exchanges among quality-management experts from all industries and regions in Korea. The government plans to implement the campaign nationwide. It hopes that this campaign will lay a solid foundation for developing Korea into a global technology leader with high quality standards.[92]

ROLES OF THE KOREAN STATE IN IT STANDARDIZATION

In Korea, the state has important roles in the late-standardization process of firms across all industries. The roles of the state are particularly important in the ICT sector for which standards are indispensable. One critical role of the state in IT standardization is to establish institutional frameworks. In our case study, the Korean state had played the leading role in IT standardization during the early stages of the development of its ICT industry. Mainly through the Ministry of Information and Communication (MIC) and the Ministry of Commerce, Industry and Energy (MOCIE), the Korean government has always been in charge of IT-related standards activities both domestically and internationally.

Under the MOCIE, the Korean Agency for Technology and Standards (KATS) represents the country in the ISO and the IEC and manages overall standardization policies and strategies. The Korean Industrial Standards Institute (KISI) plays a role as the domestic secretariat of Korean standards committees deliberating KS standards in the IT field and supports the of the standardization initiatives of KATS implementation.

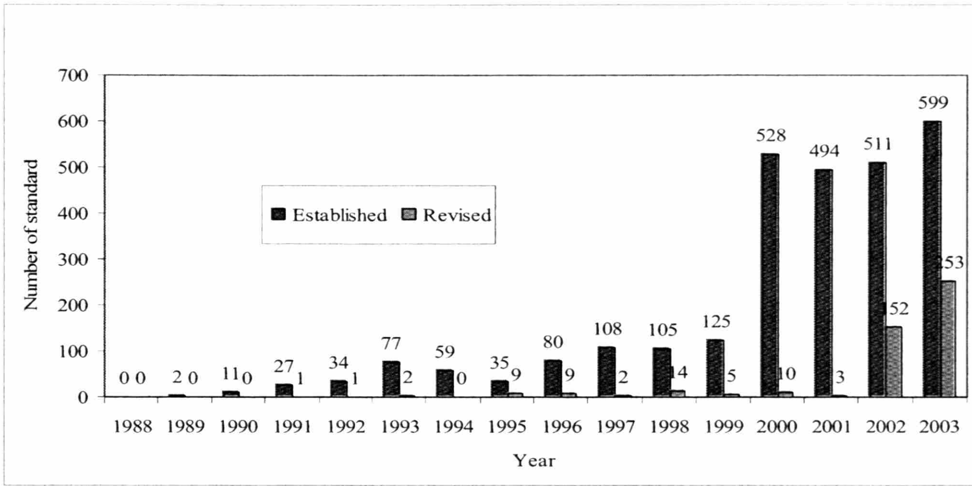
On the other hand, the MIC has been the main agency dealing with telecommunication standards in Korea, representing Korea in the ITU. Although the MIC and the MOCIE are both responsible for ICT-related standardization, each is responsible for different technical aspects and areas. To some extent, there is a clear division of labor between the two ministries, although some of the responsibilities are overlapping. Both ministries normally meet once or twice a year to discuss ICT standardization issues. One of the objectives of such meeting is to map out the important technical areas to which the government should pay attention. Then, the ministries are to determine which agencies will be responsible for what technical areas, and which working groups/committees in the ISO, the IEC, and the ITU they are to participate. Both ministries usually discuss and jointly decide on the issues. If and when they cannot reach any conclusion, the Office of the Prime Minister office will have to intervene, coordinate, and resolve the issues in question.[93]

The turning point for IT standardization in Korea, especially for the MIC, was in the late 1980s, when the Telecommunications Technology Association (TTA) was conceived and finally established in 1988 under Article 32 of the Civil Law. The TTA was later expanded re-incorporated in 1992 under Article 30 of the Framework Act on Telecommunications.[94] The establishment of the TTA indicates a significant shift from the state-led approach to ICT standardization to public-private partnership and eventually to private-sector-led approach.

With the TTA establishment, two levels of ICT standards became available in Korea: TTA standards and Korean Information and Communication standards (KICS), approved by the Ministry of Information and Communication. TTA standards are industry standards which may be proposed by individuals or organizations and finally approved by the TTA. On the other hand, KICS are official government standards. A TTA standard can be proposed as one of KICS, if it survives as an active standard through one-year field experiments.

Although the TTA was established in 1988, its standardization activity was active until the year 2000, when the number of standards increased more than fourfold in just one year (Figure 7.4). The number increased from an annual average of less than 50 standards in the early 1990s to about 100 standards in the late 1990s, and jumped to more than 500 standards per year since 2000. The total number of TTA standards that were established and revised during 1988-2003 is 3,256 standards.

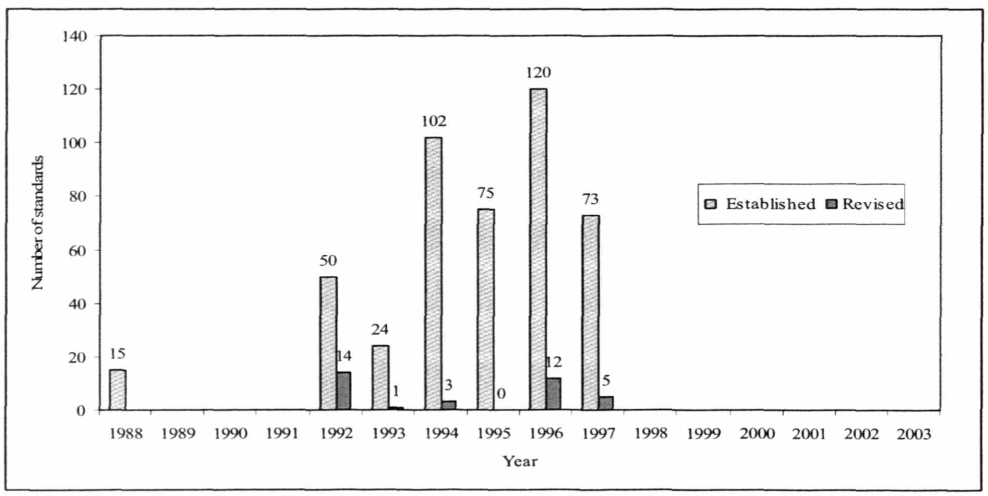
Figure 7.4: Number of TTA Standards, 1988-2003



In contrast to the increase in TTA standards, the MIC has issued very few KICS standards in recent years. The ministry was active in issuing KICS during 1992-1997, approving as many as 120 new standards in 1996. However, the number has dropped drastically since 1998. According to Sanghoon Lee, an MIC official who worked on KICS, the ministry has approved only two or three KICS since 1998.[95] It was also during this period when the number of TTA standards started to increase dramatically.

There are various reasons for the sharp drop in KICS and the spike in TTA standards. The MIC has too few personnel working on KICS to keep up with the rapidly changing ICT technologies. As a growing number of IT standards are now developed by a large number of international consortia, the MIC alone does not have enough resources to assume all the responsibility to develop and maintain IT standards. In addition, governmental standards, such as KICS, carry important weight and directly affect the strategies and operations of the private sector. With the rapid technological change, there is huge risk that the government may decide too early on certain standards as national standards, and/or choose totally wrong standards. Because government-mandated standards are more difficult to modify and adjust than industry standards, the MIC has become more reluctant to issue KICS. Furthermore, the Korean government has become more cautious in mandating any technical regulations and standards that may violate the WTO agreements, particularly the Technical Barrier to Trade (TBT) Agreement. Therefore, the MIC has shifted its role from being the main developer and issuer of mandatory national standards to supporting the TTA to become the main forum for ICT standardization in Korea.

Figure 7.5: Number of KICS Standards, 1988-2003



Source: TTA Annual Report, 2004

The TTA thus functions as the central organization for IT standardization in Korea. This indicates the shift from the government-led approach to industrial standardization to the private-sector-led approach. The TTA works extensively with firms, state agencies and research institutes. Although the TTA is legally a non-governmental body, its status became contentious when the Office of the U.S. Trade Representative (USTR) claimed that a TTA standard for Wireless Internet Platform for Interoperability (WIPI) created a trade barrier. In its letter to the USTR regarding this issue, the Advancing the Business of Technology (AeA), a U.S. trade association, argues that the TTA is "quasi-governmental", and that:

> [t]he TTA is … a subordinate organ of the MIC, and is chaired by a Korean Government official who has vice-minister status in the MIC and who is head of MIC's research and development entity, the Electronics and Telecommunications Research Institute (ETRI). The MIC is estimated to have contributed, directly and indirectly, between $11-14 million to develop WIPI[96]

The Korean government and TTA officials whom we have interviewed argue firmly that the TTA is not a governmental agency, but a non-governmental organization. This assertion is understandable. Because of the increasing conflicts among Korea and other trading partners, as well as the WTO agreements on trade barriers, any organization risks being accused of receiveing governmental subsidies that constitute trade barriers.

However, the TTA does receive a significant proportion of its operating budget from the Korean government. As shown in Table 7.4, income from entrusted research projects constitutes the largest proportion of budget for the TTA. Although this may not be a direct governmental subsidy, it is a form of state support for standardization activities by the private sector. Although this is not the place to determine whether this financial support constitutes "subsidies," it is important to note that the government still plays a significant, though indirect, role by providing financial support for standardization activities.[97]

Table 7.4: TTA Budget Allocation, 2003 and 2004 (million KRW)

Budget Items	2003	%	2004	%
Allotted charges for project participation	566	2	800	3
Interest income	475	2	450	1
Income from entrusted research project	23,231	87	23,360	76
Balance brought forward	964	4	2,064	7
Other	1,545	6	4,003	13
Total	26,801	100	30,677	100

Sources: TTA Annual Reports 2003, 2004

The important roles played by private standardization bodies, such as the TTA, demonstrate the changing role of the state in the process of late standardization. In the case of the TTA, this is reflected in its increasing role as the main organizer and facilitator of IT standardization. In addition to its role as the issuer of TTA standards, the TTA functions as the main coordinator and facilitator of IT standards-related networks in Korea. How the TTA and, for that matter the MIC, promote networking among firms and institutions is the main topic for the following discussion.

PROMOTING NETWORKING BASED ON COMMON STANDARDS

Another important role of the state in the late-standardization process is to facilitate networking between late-standardizing and forerunner firms, as well as among late-standardizing firms themselves. As defined by Powell (1990), networks are groups of entities (organizations or individuals), in which exchanges and transactions are indefinite and sequential and occur through reciprocal, preferential, mutually supportive actions. Firms create indebtedness to one another and mutual reliance over the long run. Firms in the same network are dependent on the resources of one another as they see that it is mutually beneficial to pool resources. Networks are useful in exchanging commodities where value is hard to measure. Knowledge is a classic example of such commodity. Trust and mutual dependency often facilitate more rapid flow of information among entities in the same network.

Networking is an important part of the Linking apparatus, which, we argue, late standardizers can use to leverage for more external resources so as to progress beyond catch-up. As shown by Amsden and Chu (2003) in their study of Taiwan, the state plays a significant role in increasing domestic networks in the electronics industry, even though relationships among domestic networks are not as strong as those between domestic and multinational firms. Networks in the form of subcontracting are an important mode by which latecomers gain technological capabilities by linking with multinational firms. Another important model of government-led networking in Taiwan is to develop and invest in governmental research institutes and then to create spin-offs from the institutes.[98] Such spin-offs then serve as the lead firms for other smaller firms in the country.

In our cases of the Korean semiconductor and mobile telecommunication industries, we find that the Korean government has been active in facilitating and creating networking among local firms in addition to creating linkages between local and foreign firms. The aim of recent government-led networking is not so much to create buyer-seller networks through subcontracting. Rather, the goal is to facilitate the exchanges of information and knowledge on new technologies and businesses among domestic firms. The government has directly and indirectly supported the establishment of domestic forums and consortiums, in which local firms participate to exchange information on new technologies and standards. Some of the forums actually take on the role of developing and diffusing industrial standards within Korea.

The role of the Korean state in enhancing domestic networking is particularly important in the ICT sector for which standards are indispensable. One important institution that has functioned as the main actor in creating and facilitating the domestic networks is the Telecommunication Technology Association (TTA). The TTA is a non-governmental, statutory organization that was established to improve and develop telecommunication technologies and standards in Korea.

The number of standards forums and consortia promoted by the TTA has increased significantly in the past few years, from only 11 forums in 2000 to 33 in 2003, and 35 forums in 2005.[99]

Table 7.5: Domestic Forums for IT Standardization in Korea

Year	2000	2001	2002	2003	2005
Number of Forums	10	22	29	33	35
Number of member firms/organizations	820	1,215	3,270	n.a.	n.a.
Number of individuals involved	2,765	3,250	6,920	n.a.	n.a.

Source: TTA Annual Report, various years

The forums cover a wide range of technical areas in the ICT sector, including wired and wireless telecommunication, internet, broadcasting multimedia, and digital contents. Table 7.6 lists the standards forums promoted by the TTA in 2003. The total number of members in these forums is astonishing: more than 11,000 individuals from private firms and 3,500 individuals from research and governmental institutes have become members of these forums.

Some forums are more popular than others, indicating the level of importance and interest in the industry. For instance, among the largest forums, the VoIP Forum has 185 company members and almost 3,200 individual members, and the Wireless Internet Standardization Forum has almost 2,000 firms and 2,500 individuals as members. On other hand, the Uniform Resource Identifier (URI) Forum has only 8 company members and 120 individual members.

Table 7.6: Domestic Strategic Standardization Forums Promoted by TTA, 2003

Technical Areas	Names of Forum	Membership		Output	
		Firms	Individuals/ Institutions	Standards	Technical Reports
Network and Transmission Technology (10 forums)	Korea Optical Internet Forum	40	40	25	41
	Grid Forum Korea	213	820	20	NA
	Korea Ethernet Forum	50	100	7	30
	Broadband Convergence Network Forum	121	320	48	34
	xDSL Forum	NA	NA	1	3
	LBS Standardization Forum	61	4	3	-
	Telematics Forum	79	-	1	-
	Korea UWB Standardization Forum	NA	89	NA	NA
	RFID Forum*	115	50	NA	NA
	High Speed Wireless LAN Forum	13	100	2	15
Internet (5 forums)	IPv6 Forum Korea	79	153	15	92
	VoIP Forum	185	3,191	7	-
	Uniform Resource Identifier (URI) Forum	8	120	10	-
	Wireless Internet Standardization Forum	1,183	2,452	11	7
	Web Korea Forum	17	145	6	-
E-Commerce (5 forums)	Korean Electronic Payment Forum	103	48	14	-
	Internet Security Technology Forum	58	114	23	6
	Integrated Forum on Electronic Commerce	350	30	33	-
	Korea Biometrics Forum	39	26	25	-
	Business Process Management (BPM) Forum	NA	NA	7	NA
Broadcasting and Multimedia (3 forums)	Advanced Digital Broadcasting Forum	25	NA	8	8
	MPEG Korea Forum	18	1200	9	115
	Korea Digital Cable Forum	40	20	3	-
Digital Contents (3 forums)	Digital Rights Management (DRM) Forum	25	120	5	4
	Digital Content Forum	41	15	9	-
	Mobile 3D Standardization Forum	25	11	-	-
Appliance (2 forums)	Home Network Forum	NA	NA	NA	NA
	IT Accessibility Forum	26	30	1	34
Software (2 forums)	Software Component Standardization Forum	109	24	23	-
	Open Source Software Promotion Forum	NA	NA	NA	NA
Parts and Others (1 forums)	System on Chips (SoC) Forum	13	60	4	0

Source: TTA Website, URL: www.tta.or.kr, and TTA Annual Report 2003.

The standards activities in these forums are more broad-based than those in the TTA committees, in that they are less formal and do not necessarily result in setting standards. Once technical specifications and standards are developed within the forums, they are then proposed to the TTA for consideration. The TTA committees accept proposals from the standards forums, and then evaluate them to determine whether to adopt the proposals as TTA standards. This procedure facilitates the standardization process within the Korean industry. The exchanges within the forums allow Korean firms to keep up with rapid technological change. In the several technical areas where Korean firms are the world's technology leaders, the standards forums allow firms to standardize the technologies before their foreign competitors. Approximately 2,500 individuals participate as members of the TTA in its four technical committees and 48 project groups (Kim 2005).

INSTITUTIONAL COMPLEMENTARITY

As a late-standardizing country, Korea has a variety of options and models to follow when setting up its institutional framework for standards activities. The options range from the private-sector-led model as in the United States to the state-led model in France and several other countries in the European Union. The recent institutional arrangement for standards activities in Korea indicates that the country is not following a single country as a model. Rather, the domestic standards institutions increasingly resemble the institutional arrangements of international standardization.

The goal of such an arrangement is to benefit from institutional complementarity. As Mattli and Buthe (2003) empirically show, other things being equal, differences in institutional complementarities are a significant determinant in putting firms from different countries or regions in a first- or second-mover position when standardization becomes global. If that is indeed the case, the Korean late standardizers certainly will benefit from the domestic institutional arrangements. As Table 7.7 shows, most of the domestic standards forums supported by the TTA are aligned with both formal and "informal" standards forums at the global level. This alignment allows Korean firms and institutions to focus on relevant issues and participate more actively in international standardization. They also gain better and more quickly the information about international standards proposals than they would otherwise.

Table 7.7: Institutional Complementarity between Korean and International Standards Forums

Technical Areas	Domestic Forums	International Standards Organizations	
		Formal SDOs	Consortia and Forums
Network and Transmission Technology	Korea Optical Internet Forum	IUT-T SG13	IETF, OIF Forum
	Grid Forum Korea	ITU-T SG16, ETSI	GGF
	Korea Ethernet Forum	ITU-T SG2, ETSI	IEEE802.1, 3, 17
	Broadband Convergence Network Forum	ITU-T SG13	IETF, MSF, Parley
	PKI Forum	-	IETF, IEEE802.1
	LBS Standardization Forum	ISO TC 211(GIS)	OMA-LOG, OGC
	Telematics Forum	ISO TC 204(ITS	OGSi, AMI-C, 3GT
	Korea UWB Standardization Forum	-	IEEE802.15, Wi-media
	RFID Forum	-	-
	ITS Forum Korea	ISO TC 204(ITS	ITS Forum
Internet	IPv6 Forum Korea	-	IETF, IPv6 Forum
	VoIP Forum	ITU-T SG16, ETSI	IETF, IMTC
	Uniform Resource Identifier (URI) Forum	ITU-T SG2	IETF, ENUM Forum
	Wireless Internet Standardization Forum	ITU-T SG2, ETSI	OMA, 3GPPs, IETF
	Web Korea Forum	ITU-T SG2, ETSI	W3C, OASIS
E-Commerce	Korean Electronic Payment Forum	JTC1 SC17	EMVco, VPnC
	Internet Security Technology Forum	JTC1 SC27	IETF
	Integrated Forum on Electronic Commerce	UN/CEFACT	OASIS, OMG
	Korea Biometrics Forum	JTC 1 SC37	Biometric Consortium
	Business Process Management (BPM) Forum	-	WfMC, BPMI, OASIS
Broadcasting and Multimedia	Advanced Digital Broadcasting Forum	ETSI	World ADB, TV anytime
	MPEG Korea Forum	JTC1 SC29	-
	Korea Digital Cable Forum	ITU-T SG2	CableLabs, DVB
Digital Contents	Digital Rights Management (DRM) Forum	JTC1 SC29	IETF, W3C, IDF
	Digital Content Forum	JTC1 SC36	ONIX, DCMI
	Mobile 3D Standardization Forum	-	Khronos Group
Appliance	Home Network Forum	JTC1 SC25	DLNA, OSGI, UNnP
	IT Accessibility Forum	JTC1 SC35	W3C, WAI
Software	Software Component Standardization Forum	JTC1 SC7	OMG
Parts and Others	System on Chips (SoC) Forum	-	VSI-A

Source: Kim (2005)

Allocation of limited resources

Another role of the state in late standardization concerns allocation of limited resources for the purpose of standardization. In addition to financial support for standardization activities, the Korea government plays a direct role in allocating frequency for the development for WiBro, a wireless broadband internet technology being developed by the Korean telecoms industry. In February 2002, the Korean government allocated 100MHz of electromagnetic spectrum in the 2.3GHz band for WiBro. This is an important step, as it suggests a proactive role that the government played in standardization activities.

Capability enhancement for standards personnel

As with any sector and field of the economy, human capital is an important factor in the field of standardization. The MIC and TTA have devised and implemented various policies and programs to enhance Korea's capability in the area of IT standards. For instance, the government provides approximately 100 people each year with financial and other support for participating in international standardization meetings. The MIC and TTA also provide a wide range of training programs for government officials and employees of private firms.

The initiatives sponsored by the Korean government are, of course, not without criticism. Yet, their effects on the development of indigenous technological capabilities are undeniable. The government programs lower the cost of basic research and plant modernization. Its financial support for university and other educational programs improves the availability of scientists and engineers. This maintains a pool of researchers and technical experts required by the industry. In addition, government initiatives often facilitate the coordination among different entities. This reduces overlapping and redundancy of effort and contributes to synchronized development. Last but not least, the government is the main actor behind the development of a science culture and a strong technological infrastructure within the society.

MITIGATING TECHNOLOGY AND MARKET RISKS

Another important role of the state is to mitigate the risks that late standardizers often face in their process of late standardization and technological catch-up. As identified by Lee et al. (2005) in their study of Korean firms in the digital TV industry, latecomers generally face two types of risks in their catch-up efforts: that is, technological risks and market risks. We argue that the state plays a significant role in reducing technological and market risks through various policies and programs, as follows.

TECHNOLOGICAL RISKS

For latecomer firms with limited resources and technological capability, the tasks of searching and selecting the right technologies for their products and production processes are daunting, if not impossible. They have to deal with technological uncertainty and risks to a greater extent than fast-follower and first-mover firms, mainly because of a limited technological base, as well as inadequate knowledge about technological trends and trajectories. They may end up choosing inferior technologies or adopting wrong standards that will not be accepted by the marketplace.

The state can play an important role in assisting latecomer firms in dealing with technological risks. Through the establishment of R&D institutes, the state can mitigate the technological risks faced by latecomer firms by taking the early stage of technological search and selection. The state can also play a significant role in acquiring new technologies from foreign sources, then analyze, enhance, and diffuse such technologies to domestic firms. This role is important, especially for technologies are to become industry standards.

The Korean government has devised and implemented various policies and programs to deal with technology risks associated with standards and standardization. In our case study of the mobile telecommunication industry, the government played the leading role by selecting the CDMA standard as the national standard for mobile communications. Particularly, the MIC played an essential role in the development of mobile telecommunication industry in Korea. As the domestic mobile telecom industry was seeking ways to reduce its dependence on foreign technologies, the MIC launched the Digital Mobile Telecommunication System Project 1989, which aimed to develop a total mobile service system for Korea, including base systems, switching stations, and handsets (Lee and Han 2002).

Combining efforts with ETRI, the MIC led the public-private consortium that took charge in searching, analyzing, acquiring, and eventually diffusing the new technologies that they acquired from, and co-developed with Qualcomm. The role of the MIC and ETRI was paramount to the recent success of the Korean late standardizers in the mobile communication industry. Particularly, ETRI was the main research institution that led to the selection and development of the CDMA-based mobile communication system. The main task of ETRI was to acquire and analyze knowledge on technological trajectories, emerging technologies, and the sources of such technologies. Throughout the process of searching and acquiring new technologies, the government worked constantly with the private sector, particularly the

Chaebols, such that their efforts would effectively lead to the development of local technological capabilities. Such co-operation with the private sector is often done in Korea through specially designated task forces, working committees, or formally established consortia. Once the technologies are acquired, the government disseminates the knowledge to the private sector, often through research institutes, such as ETRI.

For many products and industries, standards are initially developed and even settled before the markets are formed (Lee et al. 2005). This makes the knowledge of technological trajectories even more critical to late standardizers' effort in developing new products based on such standards. It also affects how late standardizers adjust and prepare their production processes for the new technologies and products. Participation in standards development allows firms to learn about the directions in which the technologies are evolving. When late-standardizing firms still have limited resources and standards capabilities, the government plays a leading role in acquiring, assessing, and then diffusing such information on behalf of late-standardizing firms. This role of the state remains important even when firms become more advanced and have adequate resources and capabilities for standards purposes. This is particularly true for governmental research institutes, which deal with cutting-edge technologies that are still at the pre-competitive stage and far from commercialization.

MARKET RISKS

Securing initial demand for new products is a critical and difficult task for any firm. For latecomer firms, such task appears even more daunting, primarily because of small domestic market and limited knowledge about the lead-user markets in advanced economies. The latecomer state may adopt various policies and programs to reduce market risks.

One policy is to choose a specific standard among a pool of potential standards and designate it as the national standard. By doing so, the domestic market is somewhat guaranteed for such standard, which effectively reduces the market risk for domestic manufacturers and service providers adopting such a standard. In addition, the latecomer state may adopt procurement policies that help build the initial market demand for latecomer firms' products based on the national standard.

Especially in the network industries, such as telecommunications, firms that can quickly capture the large market share from the beginning have a greater probability to become dominant in the market. State intervention greatly affects technological rents during when product innovation is the main driver of innovation dynamics. One of the most important determinants of technological rent during that time is standardization. In other words, the state could potentially create the value for firms.

As the case of the Korean mobile telecommunication industry, the government secures initial market size for domestic manufacturers and service providers by selecting CDMA as the national standard. The government's eventual selection of the CDMA standard over other potential standards was not without controversies and conflicts. Yet, the recent ascent of Korean manufacturers and service providers as the world leaders in mobile telecommunication proves that the government's decision was right. By choosing CDMA as its national standard, the government in effect guaranteed a sizable initial market and economies of scale for the service providers and handset manufacturers.

The degree of state involvement is not uniform across industries and stages of late standardization and technological catch-up. Compared with the public-private consortium for CDMA development produced remarkable results, a similar consortium established in 1986 by the government to develop 4M DRAM was less successful. Despite the government contribution of 57% of the total expenditure (USD 110 million), the consortium became a failure. The main reason was that the participating firms, including Samsung, Hyundai, LG, were not willing to share knowledge, as they had different technology approaches and enough resources and technological capabilities to go alone (Kim 1997).

By the late 1980s, the semiconductor industry had somewhat matured; radical innovations happened less frequently and the technological trajectory became more predictable. On the one hand, catch-up initiatives at this stage were "path-following" in nature (Lee and Lim 2001) and less risky. Latecomer firms with adequate resources and capabilities were thus able to engage in catch-up efforts without relying much on the state. On the other hand, in the industries where radical innovations are still frequent and standards are yet to be determined, catch-up efforts by late standardizers have to be "path-creating" (Lee and Lim 2001). Because technology and market risks are high in such stage, the role of the state to cushion such risks for the late-standardizing firms is indispensable for their technological initiatives.

Clear visions and strategies: IT839 Strategy

In 2003, the Korea Ministry of Information and Communication (MIC) set forth the IT839 Strategy for the development of the Korean IT industry. The strategy aims to develop eight communication broadcasting services, three infrastructures (networks), and nine IT new growth engines synthetically. In the case of the IT industry, the introduction and activation of new services are closely linked with the expansion of investment in infrastructure and the development of state-of-the-art machinery, tools and content industries.

ROLES OF GOVERNMENTAL RESEARCH INSTITUTES

As discussed in earlier chapters, the roles of governmental research institutes are critical throughout the process of late standardization and technological catch-up. In the case of Korea, the Electronics and Telecommunications Research Institute (ETRI) was one of the key actors in the successful development of Korean telecommunication industry. Similarly, the Korean Institute of Electronics Technology (KIET) was also instrumental in the development of Korean semiconductor industry.

The roles of these research institutes were not limited to conducting R&D in laboratories. They contribute significantly to the catch-up process by searching and identifying existing technologies and standards, as well as in analyzing and predicting future technological trends. These activities are crucial for late standardizers, particularly during the catch-up and keep-up periods when their search capabilities are still limited. They contribute mainly to reduce the technology risks associated with new technologies and standards.

STATE AS THE MODEL USER

As with the role of the state in the late-industrialization process, the state can also become a role model for the private sector in the process of late standardization. As Amsden (2001) argues, state-owned firms are often "national champions," which function as the model producers for other domestic firms. In a similar vein, we argue that, in the late-standardization process, the state can become the model user for certain standards by utilizing its procurement policy and practice. Particularly, in the IT sector, the state can become the model user as part of the so-called "E-government" initiatives. These initiatives are now being adopted widely in many countries around the globe.

The Korean state has acted as the model user in the IT sector by using advanced information technologies in governmental activities. For instance, under the National GIS Plans (1^{st} stage: 1995-2000, 2^{nd} stage: 2001-2005), the government completed systems for topographical and thematic maps. The government also promotes the establishment of a comprehensive logistics information network. This includes the Intelligent Transportation System (ITS) 21 Project, which was launched in 2001.

STANDARDS DIPLOMAY FOR OVERSEAS MARKET EXPANSION

As late-standardizing firms improve their innovation capabilities, the state furthers its standards effort beyond borders. This international endeavor is not limited to participating in global and regional standardization activities. It includes lobbying and negotiating with other governments, so that those countries adopt its technologies and standards as their national standards. Although the main goal is to increase the demand for its technologies and products, this "standards diplomacy" goes beyond "technology diplomacy. As standardization becomes more internationalized and globalized, the role of the state as a lobbyist for market expansion becomes even more pronounced.

In our case study, the Korean government has increased its international standards effort both in terms of active participation in regional and international standardization and in terms of lobbying other governments to adopt Korean technologies and standards. For instance, the Ministry of Communication and Information (MIC) has actively participated in regional standardization activities, notably the Asia Pacific Telecommunity (APT) as well as the China-Japan-Korea (CJK) Standards Meeting. The CJK Meeting is particularly noteworthy, because it shows the effort to form a regional trade and technological bloc based on standards.

China-Japan-Korea (CJK) Standards Meeting

Another important initiative that exemplifies the role of the Korean state in regional standardization is the China-Japan-Korea (CJK) Meeting on Information and Telecommunication Standards. The CJK Standards Meeting is a forum in which standards development organizations and firms from China, Japan, and Korea exchange views and information on information and communication technologies and industries. The Meeting was first conceived and initiated by the Korean Ministry of Information and Communication (MIC) and the Telecommunications Technology Association (TTA). Other standards organizations from Japan and China then joined the initiative, including the Association of Radio Industries and Businesses (ARIB) and the Telecommunication Technology Committee (TTC) of Japan and China Communications Standards Association (CCSA) of China.

According to Sanghoon Lee, an MIC officer, the Korean MIC first proposed the collaboration among Korea, Japan, and China in a statement prepared by the Korean MIC for the ITU. The Korean MIC officers first approached Japan's Ministry of Internal Affairs and Communications (MIC) and China's Ministry of Information Industry (MII).[100] The proposal has led to the formation of the CJK Standards Meeting and the three countries have held five meetings to date: the 1st CJK meeting in June 2002 in Korea, the 2nd in November 2002 in Japan, the 3rd in November 2003 in China, the 4th in July 2004 in Korea, and the 5th in March 2005 in Japan (Maeda et al. 2005).

The CJK Standards Meeting could have potential impacts for latecomer firms and institutions in Korea and China in various ways. First, although currently the main activities of the CJK Standards Meeting focus more on information exchange among the members, the eventual goal of the Meeting is to develop common regional standards. Several standards development activities are conducted jointly by representatives of firms who participate in the forums organized by the SDOs as part of the CJK Meetings.

Second, the cooperation between the four standardization bodies increases their individual negotiation power in standardization activities at the global level. The meetings between the four SDOs give them opportunities to discuss issues that may be raised in the global forums such as the IEC and ITU. They may be able to agree to support each other's technical proposal for standardization at the global level. This strategy has already been used by European SDOs, which coordinate their standard strategies and actions through the ETSI.

Third, the cooperation enlarges the potential markets for emerging technologies if the member countries adopt common standards. As the geographical scope for ICT standardization activities cannot be limited to a country, it is important that technology holders find more adopters outside their home countries.

The CJK Standards Meeting has already shown concrete results in establishing an East Asian regional bloc based on technical standards. A good example is the Next-Generation Network (NGN) Working Group of the CJK. During the 4th CJK Standards Meeting in

Beijing in June 2005, the representatives from the three countries agreed to construct an NGN testbed between the three countries. Korea plans to make the most of this arrangement to get its verified technology accepted as an international standard. In the following 5th CJK NCN WG Meeting held in Seoul in December 2005, the representatives had concrete discussions on the proposed testbed structure plus test methods and items between the three nations.

The Chinese, Japanese, and Korean governments have also supported an R&D alliance that aims to develop open-source software (OSS) programs based on Linux, in order to become independent from proprietary software developed by U.S. and European firms. The China-Japan-Korea (CJK) partnership was founded by China Software Industry Association (CSIA), Japan IT Services Industry Association (JISA) and Federation of Korea Information Industries (FKII). The partnership aims at enhancing OSS development and deployment, OS business models, software standardization at the regional level, and training of engineers.[101]

Korean-developed technologies in India and China

The overseas lobbying effort by the Korean government is an important effort that helps expand Korean-developed technologies and standards into overseas markets. This is an important role, especially when the strategy is to expand its export market first to other developing economies, instead of developed countries. In most developing countries, the governments are still the main, if not sole, developer and distributor of standards. It thus seems logical as a tactic to have the state deal first with the other state before the private sector enters the foreign market.

A recent example is the satellite Digital Multimedia Broadcasting (DMB) and terrestrial

DMB (T-DMB) services, which was offered in Korea for the first time in the world in May and December 2005, respectively. Following the domestic success, the Korean MIC signed an agreement in January 2006 with the Telecommunications Regulatory Authority of India (TRAI), India's largest business conglomerate Tata Group, and its top GSM mobile-phone service carrier Bharti Airtel to start trials of the Korean-developed T-DMB system in India.[102] Meanwhile, the Korean MIC has also cooperated with the World DAB Forum, a London-based standardization forum for digital audio broadcasting (DAB) technologies, to advance the T-DMB standard in India.

Although the private sector possesses most of the T-DMB technologies, the Korean government has been instrumental in lobbying for the Korean standards to be adopted in India. Both governments has started work-level meetings and signed a memorandum of understanding (MOU) that will help for Korean firms to obtain India's permission for full T-DMB services.

In addition to India, the Korean government has also been successful in exporting the T-DMB service to China. Also in January 2006, the Electronics and Telecommunications Research Institute (ETRI) and China's state-funded Beijing Jolon Digital Media Broadcasting signed an MOU to launch the service in the Chinese market in April 2006. To facilitate the deal, the Korean MIC has started to hold regular meetings with China's State Administration for Radio Film and Television for further cooperation on T-DMB.

The agreements between the Korean government and the Indian and Chinese governments have certainly benefited the Korean manufacturers and service providers. Samsung Electronics, for instance, already signed contracts to supply 200,000 T-DMB-enabled phones to Beijing Jolon and another 300,000 handsets to Guangdong Mobile Television Media.[103]

As a strategy to expand the export market, the Korean government has sometimes included the adoption of its domestic technologies and standards as part of the strings attached to its foreign aid. As an example, Korea has exported its time division switching (TDX) technologies and systems to the Philippines and other developing countries by attaching the adoption requirement to its foreign assistance funds.[104]

The MIC has also set up the International Cooperation Agency for Korea IT (ICA) specifically to promote Korea's IT products in the overseas market. The activities of the ICA extend beyond the usual export promotion, in that they incorporate IT-related issues into international cooperation activities. Through the activities of the ICA, the Korean government aims to promote its domestic technologies and standards overseas.

PROTECTING INTELLECTUAL PROPERTY RIGHTS

As late standardizers enhance innovative capability and move towards the technological frontier, they generate more intellectual property (IP) and standards become more important. In such a process, the state adjusts its role and policy regarding the protection of intellectual property rights (IPRs). At the early stage of late standardization and technological catch-up, the state may not strictly enforce IPR laws. The idea is to allow local firms to take advantage of technology transfer from foreign firms through licensing and reverse engineering. However, as latecomer firms become more innovative and possess more proprietary knowledge, the state has to increase its effort in enforcing the protection of intellectual property rights. The state may tie its IPR policy to standards policy by adopting national standards that include technologies proprietary to local firms. Even if the IPR policy does not directly address standards issues, IPR policy is an important factor that affects late standardization process of latecomer firms. In addition to arranging the legal and institutional structures for IPR protection, the state also plays an important role in providing knowledge and information regarding IPR protection both in the domestic and foreign markets.

The Korean experience in late standardization is a good example. Historically, IPR protection in Korea has been weak (Jung 1996). According to the United States International Trade Commission (1988), Korea was found to have a "large amount of end-user software piracy, particularly by large conglomerates; lack of recognition of well known trademarks; failure to protect pre-1987 works under the copyright law; lack of protection for trade secrets and software and motion picture import valuation"(as quoted in Jung 1996, page 1).

According to Jung, the real problem was not that Korea had no laws for intellectual property protection. Rather, it was a problem of enforcement. Despite that Article 21(2) of the Korean Constitution provides the legal basis for IPR protection, the enforcement of this law has not been effective. Jung argues that the lack of adequate enforcement is due to Korea's socialist values. Intellectual property rights are greatly affected by the Korean cultural belief, which hold that the interests of society as more valuable than those of an individual.

Another important reason for Korea's weak IPR protection is related to the effect of IPR regimes on technology transfer. As Kim (2003) argues, the Korean state did not enforce its IPR laws, because a strong IPR regime would affect technology transfer and capability building of local firms. At the early stage of technological catch-up, latecomer firms do not have proprietary technologies and have to acquire them from foreign sources through various modes, including licensing and reverse engineering. A strong IPR regime would minimize the knowledge spillover in the process of technology transfer. The Korean state recognized such a possibility, so that it was reluctant to enforce the IPR protection.

However, as successful Korean latecomers generate more proprietary knowledge through R&D activities, the government has recognized the importance of IPR enforcement. As the state promotes standards activities, it has become necessary for the state to adjust its IPR protection policy and enforcement. IPR issues are critical to standardization activities, and the Korean government has increased its efforts in assisting the private sector in this regard. Each domestic standards forum often receives advice and support from the Korean Patent Office regarding its IPR policy. The TTA has full-time staffs who are specialized in IPR issues and participate in both domestic and international standardization activities.[105]

Diffusion of IPR-related knowledge is another important role of the state. Government agencies and research institutions, such as the Korean Patent Office (KPR) and the Korean Intellectual Property Research Center, play an important role in diffusing IPR-related information to domestic firms. They also facilitate exchanges among firms and government agencies regarding patent and other IPR issues, particularly in the advanced markets, such as the United States. The KPO, for instance, have organized patent forums in which successful late standardizers, such as Samsung and LG, participate to discuss IPR issues.[106]

CONCLUDING REMARKS

Technical standards are everywhere. They are so prevalent that every firm and country is involved in standards activities in one way or another. What distinguishes successful late-standardizing firms and countries from unsuccessful ones is that the standards activities are at the core of their technology policies and practices. Particularly, measurement and quality standards are the most fundamental factor taken seriously by the successful late standardizers.

In our case study of the Korean state, we find that their standards policies and programs have been not only in line with the overall industrial and technology policy, but also its central feature. Since the early stages of late standardization and catch-up, the Korean state has maintained a proactive position with regard to domestic development of advanced technology. While this is particularly true in the semiconductor and telecommunication industries, the Korean general technology policy includes other high-tech industries, such as biotechnology and space and aeronautics.

The Korean state has nurtured the domestic high-tech industries by building up resources, capabilities, and institutions for standards and related activities. In terms of resources, the Korean government has maneuvered financial and fiscal regulations and policies, such that latecomer firms, especially the Chaebols, enjoy low-interest loans, tax incentives, and duty-free import of targeted capital goods. In addition, the Korean government has built up basic infrastructure that supports the development of science, technology, and innovation. This includes physical infrastructure, such as transportation systems, and telecommunication infrastructure, such as broadband Internet networks. The construction of "science parks," such the Taedok Science Town, is a concrete example of its effort in providing infrastructure for science and technological development. In fact, one of the major institutions located in the Taedok Science Town is the Korea Standards Research Institute (KSRI).

In terms of capabilities, the government has continuously invested in science and technology education and R&D for high-tech industry. It provides direct financial support to public and nonprofit research institutes, universities, and other educational institutions, primarily through the Ministry of Science and Technology (MOST), the Ministry of Commerce, Industry, and Energy (MOCIE), and the Ministry of Information and Communication (MIC). The government often forms taskforces, alliances, and consortia with domestic and, sometimes foreign, firms to share resources and costs in developing new technologies and/or products.

In terms of institutions, various legal institutions have been set up for supporting industrial and technological development. Particularly in recent years, as Korean late standardizers enhance innovative capabilities and produce more intellectual property, the Korean state puts more effort into building up intellectual property-related legal capabilities and institutions.

To this end, the roles of social and cultural institutions are not negligible. The Korea government has devised and implemented various cultural and social policies and programs that promote sophisticated "technoculture" in Korea (Pecht et al. 1997).

In sum, as late-standardizing firms move from the positions of late adopters to fast followers, and eventually to technology and standards leaders, the state implements various standards policies and programs so that firms can capture greater technological rents. The state plays significant roles in six key ways: (1) supplying basic standards as infratechnologies, (2) securing demand by mitigating market risks, (3) promoting knowledge diffusion through facilitating networking, (4) reducing technology risks through technology search and forecast, (5) lobbying and negotiating with other states for market expansion of domestic standards, and (6) establishing institutional and legal frameworks to protect intellectual property.

CHAPTER EIGHT

CONCLUSIONS

GENERALIZABILITY OF THE LATE-STANDARDIZATION MODEL:

OTHER COUNTRIES, OTHER INDUSTRIES, AND OTHER TIME PERIODS ■

STANDARDS AS A SOURCE OF TRADE CONFLICTS ■ STANDARDS FORUMS AND COLLUSION ■

BRANDING AND LATE STANDARDIZATION ■ LATE STANDARDIZATION IN OPEN-SOURCE REGIME

Being late is often considered a negative trait. However, our study has shown that it is sometimes advantageous to be late, as long as the latecomer captures the opportunity to take advantage of their lateness. The process of late standardization and technological catch-up is, in many respects, characterized by latecomers' continuous efforts to free themselves from being late by necessity to being early or late by choice. Successful late standardizers are able to choose to become either standards followers or leaders, depending on their resources, capabilities, and strategic interests.

In our model of late standardization and technological catch-up, we argue that internal quality standardization is the fundamental activity that permits latecomers to enhance their competitive positions in the world market. Once latecomers advance manufacturing and innovation capabilities, external standards activities become the key to moving beyond catch-up. By linking with technology and standards leaders, fast followers learn new technologies and use them to improve their products and production processes. External linkages through standards activities allow them to keep up with technological change, to the extent that they can enhance ramp-up capabilities. Finally, as fast followers successfully develop innovation capabilities at the world technological frontier, they actively engage in, and often lead, standardization activities, such that they can sustain first-mover advantages.

In this concluding chapter, we explore how our research findings may be generalized and what research should be done in the future.

GENERALIZABILITY OF THE LATE-STANDARDIZATION MODEL

We have developed the model of late standardization and technological catch-up based primarily on the case studies of Korean latecomers in the semiconductor and mobile telecommunications industries during the past three decades. In the previous chapters, we have included discussions of a few Thai latecomers to examine how applicable the Korean experience may be to a less industrialized and "less standardized" economy.

In the following sections, we further examine the issue of generalizability. We discuss how the model of late standardization can be generalized in three different dimensions. We first discuss how the model is applicable to late standardizers other than Korea, then to industries other than the semiconductor and mobile telecommunications industries, and finally to time periods other than the past three decades. We also discuss how researchers may tackle these issues in future research.

LATE STANDNARDIZATION IN OTHER COUNTRIES

Although the successful late standardizers in Korea are unique in many regards, our model of late standardization may be generalized to include other latecomer countries, taking into account each country's unique economic and political characteristics. Regardless of each late standardizer' uniqueness, its options in terms of sources and types of standards at the early stage of late standardization are generally limited to adopting international or foreign standards developed by advanced firms and countries.

The issue arises as to what modes they use to acquire such standards. Generally, for late standardizers that are connected to multinational firms, either as suppliers or equipment buyers, the multinational firms function as an important mode for acquiring information and knowledge on standards and related issues. Such late standardizers may acquire standards and related information either as specifications in a packaged form or through special training that they receive from the multinationals. In this case, the knowledge related to standards and standardization disseminates very little to other local firms. The standards they adopt also reflect the requirements and conditions of the export markets more than the local markets. Because standards are an important means for diffusing technology, limited diffusion of knowledge on standards means limited diffusion of related technologies.

For late standardizers with no or little linkage with multinationals, the state functions as the main mode of knowledge transfer, most likely through governmental research institutes and standards development organizations (SDO). However, in consumer-goods markets in most developing economies, multinational firms often bypass national standards organizations and enforce the use their technical standards through the adoption of unique trademarks. Similar situation occurs in the intermediate and capital goods markets. Only in the case of mandatory standards for safety, health, and environmental protection do developing-country SDOs have control over technical specifications of products sold in the domestic markets.

Regardless of the levels of technological and standards capabilities and the modes of knowledge transfer, late standardizers have to engage in quality standardization and related activities in order to catch up with early standardizers. Quality standardization both at the firm and national levels is not merely the key to survival, but also the first step beyond catch-up. In order for late standardizers to become part of the global supply and value chains, they have to focus their internal effort on quality standardization and control. Particularly with the globalization of trade and investment and international trade agreements, domestic markets become less protected. Early standardizers that have better products and production processes will be able to continue their dominance in developing-country markets. This will put additional pressure on late standardizers to improve their quality standardization and control.

Institutional arrangements at the national level thus have to focus on the development of national standards systems that aim to improve quality of products and production processes. Because measurement and reference standards are infratechnologies, they are generally beyond the financial and technical capabilities of individual late-standardizing firms. The state, therefore, plays a direct role in acquiring, setting, and diffusing such basic standards.

In generalizing our model, we would hypothesize that the later a latecomer is engaged in internal quality standardization, the greater the direct role of the state in developing and providing knowledge on quality standards. A few exceptions may exist when the role of the state is substituted by multinational firms. These are the cases of domestic latecomers being: (1) suppliers to multinationals, (2) buyers of production equipments from multinationals, and/or (3) licensees of proprietary technologies related to production processes. The direct role of the state may also be less direct, when the international market for knowledge on quality standardization and methods enlarges. In that case, late standardizers can hire foreign consultants to help improve their internal quality standardization and control.

Future research may include other latecomer countries and their experiences in late standardization and technological catch-up. Among others, China and India are particularly worth detailed research. In many technical areas, the United States and the European Union have been able to push its domestic standards as international standards. The rise of China and India presents an interesting scenario, in which their large domestic markets may dictate not only domestic standards but also international standards. Strategically, China and India may not choose to compete directly against more advanced firms in the U.S. and E.U. markets, but compete in the emerging markets. Lower costs and somewhat advanced technologies from China have already gained grounds in several areas, including telecommunication equipment.

LATE STANDARDIZATION IN OTHER INDUSTRIES

We have selected the semiconductor and mobile telecommunications industries for our case studies, primarily because they are standards-intensive industries that have been the basis for technological catch-up efforts in several latecomer countries. As noted by Amsden and Chu (2003), late industrializers' technological upgrading since the early 1990s has mainly taken place in the electronics industry, including the semiconductor, electronic appliances, and telecommunications industries. Meanwhile, during the period since the 1990s, we have also witnessed several rapid and major changes at the technological frontier in the electronics industry, particularly with the rise of the Internet and other digital technologies. This evidence partially supports Perez and Soete (1988)'s argument that latecomers have greater windows of opportunities for technological catch-up when the techno-economic paradigms are changing than when the paradigms at in stable states. A question then arises as to whether our model of late standardization is generalizable to other industries.

Non-network industries

Information and communications technology (ICT) industries are not the only industries that are standards-intensive, even though the types of standards required are different. Because the ICT industries have strong network effects, compatibility standards are generally the main issue of contention. For non-network "high-tech" industries, such as pharmaceuticals and biotechnologies, compatibility among products is less of an issue. Yet, the industries could still be standards-intensive, in that they are a thicket of mandatory standards and regulations regarding safety, health, and the environment. Agricultural and food products are particularly subject to these types of mandatory standards.

The late-standardization effort in these sectors could be more daunting than in industries in which compatibility standards are the main issue. More often that not, mandatory standards for safety, health, and environmental protection are set by national agencies. The processes and results of standardization activities, therefore, are determined less by technical superiority as a result of competition among technologies than in the case of electronic products.

The institutional arrangements for international standardization in the areas of health, safety, and environmental protection are also different from the areas of compatibility standards. National agencies tend to take charge of setting standards and regulations at both national and international levels. As with international standardization of network products, firms and governments from developed economies continue to be influential in international standardization in the fields of safety, health, and the environment.

An important forum for international standardization in the field of food safety and health is Codex Alimentarius, or CODEX in short. CODEX is part of the United Nations/World Health Organization (WHO)'s commission to establish global standards for foods, drugs, pesticides, etc. and for their distribution and trade. Meanwhile, there is an increasing number of safety and health-related standards developed by private firms, particularly retailers, in developed economies. This adds additional pressure on late standardizers, who now face even more stringent obstacles in the agricultural and food industries, in which safety, health, and environmental standards are essential. Competitive advantage for firms in these sectors is greatly affected by the ability to comply with these standards and technical regulations as well as the conformity assessment procedures.

Arguably, our model of late standardization also applies to these sectors. Late standardizers have to focus first on the "quality" of their products, such that they meet the minimum "quality" standards related to health, safety, and environmental protection in order to sell their products in developed-country markets. They face similar obstacles as latecomers in the electronics industries, particularly those due to the limited knowledge about standards and regulations in lead-user markets and limited pool of technical experts on these issues.

Additional barriers against late-standardization efforts also exist due to the nature of standards in these sectors. Standards and regulations in these fields tend to be "performance" standards, which usually specify the minimum or maximum performance levels, as opposed to "design" standards, which indicate the actual dimensions and/or specifications of the products. Late standardizers are able to learn less from performance standards than from design standards, because they do not specify the actual specifications of components or products. This prevents late standardizers from learning through reverse engineering. They have to find other ways to innovate and produce products that meet performance standards.

As standards and regulations in these fields are developed and set mostly by public agencies, less by the private sector, the state plays an even more important role in acquiring knowledge related standards and regulations in the advanced markets. Measurement standards are also critical to latecomers in these industries, and remain as critical infratechnologies. In addition, the state has to play an important role in demonstrating the levels of compliance that late-standardizing firms have with standards and regulations in the advanced markets. Domestic institutions have to be set up such that they respond quickly and appropriately to the complex and changing requirements in the advanced markets. This requires standards capability that includes the capability to track and follow changes in standards and regulations.

Once such basic capabilities are in place, late standardizers have to become more involve in external standardization activities. International standardization in the areas of health, safety, and the environment still primarily occurs mostly in formal standards organizations such as CODEX. There are very few "informal" standards consortia in these areas, unlike in the electronics industry in which standards consortia are now prevalent. However, because each country tends to have its own sets of standards and standardization procedures,

The WTO's Sanitary and Phytosanitary Agreement, therefore, has very important implications for late standardizers, as it directly relates standards and technical regulations on food safety to international trade. This could affect how late standardizers develop their standards capability in the areas of food safety and health.

Service sectors

The service industries are another area to which our model may be generalizable. In most economies, particularly industrialized and newly-industrializing countries, the service sector accounts for the largest proportion of the Gross National Product. For instance, the service sector contributes to about 55 percent of the Korean GDP in 2005, compared with 41 percent by the industry sector and less than 4 percent by the agriculture sector.[107] Although the contribution of services to exports is still lower than manufacturing industries, with increasing globalization of trade and investment, the upward trend for global trade for services is expected to continue. The enormous potential of the services trade as an engine of export and economic growth cannot be underestimated, as services account for two thirds of world's economic activity. In fact, trade in commercial services has grown faster than merchandise trade in the past two decades. According to the World Trade Organization (WTO), world export of commercial services increased more than 200 per cent in the past decade from about US$ 1031 billion in 1994 to US$ 2,127 billion in 2004. Approximately 60 percent of the global service trade is concentrated among the top ten developed countries. Among latecomer countries, Hong Kong, Singapore and Korea are the top earners from global trade of commercial services.[108]

As with the increasing importance of standards for merchandise trade, standards will also become essential to trade in commercial services. Service standards are nothing new; companies often have guidelines and standards for services provided to customers. Yet, the focus has been within firm and sector boundaries, and, at best, national boundaries. International standardization for services has only attracted attention recently because of globalization of trade in services. Some sectors have experienced international standardization more than others. Among others, financial services have become increasingly standardized, corresponding to the globalization of financial markets. The International Monetary Fund (IMF) and the World Bank's work on financial standards and codes is a prime example of international standardization in financial services.[109]

National SDOs in some developed economies, such as Germany, and international SDOs, such as the ISO, have already started to tackle international standardization in services. For instance, the DIN, Deutsches Institut für Normung, the ISO member body for Germany, started in 2000 a project entitled "Service Standards for Global Markets," to identify the need for action and to initiate activities for developing service standards. The European Commission for Standardization (CEN) has also increased its effort in service standardization. As for March 2005, the CEN had already published 30 service standards service standards, covering areas such as tourism, transport and logistics, and healthcare. The CEN expected to publish another 43 documents related to service standards (CEN 2005).

International standardization of services is often carried out by international organizations and professional associations specialized in each industry. For instance, the World Tourism Organization (UNWTO), a United Nations agency specialized in tourism, has set up committees that work on quality standards for tourism activities. The main task of developing tourism standards, however, is undertaken by the ISO. An ISO Technical Committee on tourism standards (TC228) has been formed to standardize tourism terminology and technical specifications, as well as to adapt the existing quality management standards (ISO 9000/2000; ISO 14000) to the specificity of tourism services.

What are the implications of the increase in international standardization in commercial services for late standardizers? Because international standardization in service trade is relatively new, there is scant evidence on its effects on latecomer countries. Nonetheless, the limited standardization in commercial services presents a wide window of opportunity for late standardizers to be more actively involved in developing and setting service standards. Late standardizers with existing resources, capabilities, and institutions for standards activities for merchandise products are particularly well positioned to take on service standardization at both domestic and international levels. Korea, Taiwan, India, and China are probably capable of embarking on such efforts, depending of the areas of commercial services.

In fact, some late standardizers have already made headlines for leadership in developing and setting standards in services. Korea, for example, has recently developed and implemented the Certification System for Standard Logistics' Facilities. This is considered the first time in the world for such a logistics standard to be implemented.[110] In this case, the standardization effort in logistics services is based on the existing technological capabilities, resources, and institutions that Korea has in ICT standardization. The success points to the importance of building up standards-related resources, capabilities, and institutions in one sector, and then utilizing them as the basis for diversification into other sectors.

In sum, in generalizing our model to include the service industries, we would hypothesize that the less standardized an industry is, the more opportunities for late standardizers to benefit from engaging internally and externally in standards activities. The bottom-line argument remains that internal quality-standards activities are the basic factor on which late standardizers have to focus. As they develop standards-related resources, capabilities and institutions, they can and should engage more actively in external standardization at the international level. Because international standardization of commercial services is still not as prevalent as in merchandise products, late standardizers have more opportunities to influence the directions and outcomes.

LATE STANDARDIZATION IN OTHER TIME PERIODS

The third generalizability issue concerns whether the late standardization is applicable to time periods other than the past decade. Successful late standardization by some Korean firms has happened during the time when there are significant changes in techno-economic paradigms in the electronics industry. Analog technologies are being replaced by digital technologies, while global production chains are becoming more fragmented and globalized. This means late and early standardizers face similar technology and market barriers. The shifting paradigms thus create windows of opportunity for late standardizers to enter the new technological systems and eventually the new markets.

Therefore, in generalizing our model of late standardization and catch-up, we would hypothesize that a late standardizer is more likely to be successful in its late-standardization effort during the time when there is a change in techno-economic paradigm. Future research may test this hypothesis by examining the time periods in the past when a late standardizer caught up, kept up, and forged ahead of its forerunners. Japanese firms during the 1960s-80s are potential candidates for such a study.

OTHER ASPECTS OF LATE STANDARDIZATION

In this study, we focus mainly on the strategic, organizational, and institutional aspects of late standardization and technological catch-up, as well as the generalizability of the late-standardization model. There are, however, several other aspects of the late-standardization process that deserve more detailed investigation in future research. We list a few of them here.

STANDARDS AS A SOURCE OF TRADE CONFLICTS

The use of national standards policy as a way to nurture domestic industries will continue to be a contentious issue. This applies not only to successful late standardizers, such as Korea, but also to other developing countries in general. Particularly, large late standardizers, such as China, India, and Brazil, have shown attempts to use standards policies as part of their technonationalistic agenda.

We predict that trade disputes related to standards and technical regulations will increase within the World Trade Organization (WTO) and beyond. As countries reduce the number of tariffs and quantitative restrictions on imports, they find other ways to protect domestic industries. Compared to quantitative restrictions, standards and technical regulations are more subtle as a protectionist too and more difficult to measure with regards to their impact on trade. Nonetheless, standards policies based on protectionist agenda may not necessarily be beneficial for latecomer countries, mainly because of technological globalization.

Technonationalism and technoglobalism

The policy of unique national standards could potentially backfire, if the rest of the world adopts other standards. It is thus important that the standards policies and strategies are not based solely on technonationalism, but the have to take technoglobalism into account. Standards policies and strategies based on technonationalism may reduce the technology and market risks faced by domestic firms by identifying and supporting specific national standards. Yet, technological globalization has now intensified, in which the generation, collaboration, and exploitation of scientific and technological knowledge occurs in various locations around the globe. Individual firms and countries no longer tackle scientific and technological efforts alone. This technoglobalism, therefore, has to be taken into account in devising and implementing standards policies and strategies.

Technonationalism and technoglobalism are inherently not without contradictions. As with any public policies, while some may gain from self-reliant national standards policy, others may lose. In the case of China, for instance, local manufacturers that are mainly technology users generally prefer superior performance of foreign technologies to domestic technologies. On the other hand, the domestic technology producers, including research institutes and governmental agencies, prefer domestic technologies, even with inferior performance, in order to nurture the development of a national innovation system (Suttmeier 2005). Some manufacturers may prefer international standards to domestic ones, if their markets are primarily overseas.

These contradictions were evident in several cases in Korea, in which the government adopted the technonationalistic approach to its standards policy. When the Korean government opted for CDMA technologies as the national standard for 2G mobile telecommunication services, several interest groups and experts, both in the government and the private sector, were opposed to the selection. The government stuck to its gun and focused its efforts on developing CDMA as Korea's national standard. The policy has borne fruit, and the success in CDMA became the springboard for the subsequent success in GSM as well.

As we take a closer look at Korea's national standards policy, it is apparent that, while the policy aimed to develop self-reliance in terms of standards and technologies, the policy was not simplistic technonationalism. In the case of CDMA, technoglobalism was manifested through the constant search for foreign technologies by Korean engineers and government officers as well as the significant involvement of Qualcomm.

STANDARDS FORUMS, CARTELS, AND COLLUSION

Another aspect of late standardization worthy of detailed research is the potential problem of cartels and collusion both at the national and international levels. This problem may arise when late standardizers participate in R&D and standards alliances. Standardization organizations normally try to avoid any cooperation that may violate antitrust regulations. Yet, there are several instances, in which members of standardization forums are found to have colluded. For instance, in 2005, the U.S. Department of Justice alleged that Samsung and some other DRAM manufacturers, which were member of JEDEC, participated in "international conspiracy to price fixing". This allegation led Samsung to plead guilty and pay a $300 million fine. [111] Although the allegation did not indicate that the collusion was directly related to the technical collaboration among firms, the fact remains that these firms were all members of a particular standards club.

The potential problem of international cartels and collusion raises the question of how the regulatory regimes at the international level deal with technical collaboration initiatives that have competitive implications. So far, antitrust agencies in developed economies, particularly the United States, the European Union, and Japan, have been diligent in investigating the antitrust implications of standardization efforts by industry consortia. However, in emerging and less developed economies, this issue is hardly dealt with. In fact, some collusion as part of standardization efforts may be ignored and condoned. Firms may "cooperate" by picking industry standards that benefit the participating firms. These standards may become national standards, as in several cases of mobile telecom standards in Korea. Some of these initiatives may be considered as collusion in developed economies, but are regarded as part of national strategy to nurture local firms. Future research may reveal how legal institutions deal with the antitrust aspects of the late-standardization process.

BRANDING AND LATE STANDARDIZATION

Standardization leads to less differentiation of products offered in the market (Swann 2000). As products become less differentiated, brand identity becomes more crucial to attracting buyers. In the process of late standardization, latecomer firms are faced with the challenge of how to create brand identities while engaging in standardization activities.

The successful cases of late standardization of Korean firms, particularly Samsung and LG, indicate the paramount importance of branding. Samsung Electronics, for instance, has been implementing aggressive branding strategies while developing production, innovation, and standards capabilities. So have LG and other late-standardizing firms in Korea. More detailed research is necessary to disentangle the strategies involved in branding and standardization.

LATE STANDARDIZATION IN AN OPEN-SOURCE REGIME

We have discussed late standardization and technological catch-up in a proprietary regime, in which technological knowledge is mostly proprietary to firms in advanced economies. A question arises as to whether late standardization and catch-up would happen in a similar way in an open-source regime, in which knowledge is more publicly accessible. There is now increasing evidence and literature on the contribution of open-source software development to technological development in developing countries. The issue of open source regime may be unique to the software industry. However, as the industry is particularly standards intensive, what we learn from future research on late standardization in an open-source regime may become important lessons for other industries as well.

NOTES

CHAPTER ONE

[1] "Late standardization" could also refer to the process in which firms participate in standardization processes after some level of market stability is achieved. The opposite is "early standardization" in which standardization efforts start before the market is stable. Although the definition adopted in this dissertation includes that meaning, it is more inclusive. It is also in line with the term "late industrialization", the difference being that the focus is on standardization in instead of industrialization.

[2] Infratechnologies are technical tools that provide the technical basis for industry standards, which underlie efficient R&D, process and quality control, and the transactions of technology goods and services. Infratechnologies include measurement methods, science and engineering data, and specifications for open systems. In most developed economies, government laboratories play a leading role in providing infratechnologies, for instance, the Measurement and Standards Laboratories of the U.S. National Institute of Standards and Technology (NIST). (Tassey 1997)

[3] For detailed accounts of how standards develop, see Krislov (1997); Verman (1973).

[4] According to Rumelt (1987) entrepreneurial rents are "the difference between a venture's ex post value (or payment stream) and the ex ante cost (or value) of the resources combined to form the venture (p.143). Furthermore, entrepreneurial rents also refer to the addition of value by the combining of resources in new combinations, or the discovery, or creation of new resources, or modes of organization. They thus apply to the entrepreneurial discovery of resource value." (Ibid., p.144) Whereas Ricardian or Paretian rents can be earned in a situation of equilibrium where resource values are widely known, entrepreneurial rents apply to a situation of disequilibrium when resource value is not widely known or anticipated (Lewin and Phelan 2000).

[5] An interface standard allows the exchange of information between two or more different systems or pieces of equipment. In telecommunications, for instance, an interface standard describes functional characteristics, such as code conversion, line assignments, protocol compliance, or physical characteristics, such as electrical, mechanical, or optical characteristics. An interface standard may include operational characteristics and acceptable levels of performance (Source: www.wikipedia.com).

[6] A transaction standard is defined as description of technical or procedural elements that are necessary for market transactions to take place between two or more entities.

CHAPTER TWO

[7] A dynamic model normally represents the behavior of an object over time, where the object's behavior is best described as a set of states that occur in a defined sequence. The components of the dynamic model are: states, state transitions, events, actions, and activities (http://www.chambers.com.au/Sample_p/og_dm.htm).

[8] For more examples of recent de facto standards, especially those in the information and communication technology sector, see http://www.webopedia.com/TERM/D/de_facto_standard.htm and www.wikipedia.com, search for de facto standards.

[9] An interesting question arises here whether this argument applies to the case of producers of parts and components who produce products according to specifications ordered by other firms. Empirical researchers have not yet analyzed this issue systematically.

[10] But at some point, congestion occurs and the benefit can actually become a cost, that is, negative network externalities.

[11] See Grindley (1995) for cases and stories of standards strategy and policy in various industries, including

computer systems, high-definition television, and telepoint cordless phone.

[12] In the diagram of late standardization in Figure 2.2, we show the second to the fourth steps, omitting the first step for the sake of graphical presentation.)

[13] Digressing momentarily, we could hypothesize that technological development could be limited by the extent of the standards, because standards affect the division of labor. As Adam Smith famously argues, division of labor is limited by the extent of the market. Standards, in many respects, could expand the extent of the market, which, in turn, increases the division of labor. Assuming technological change and development is correlated with division of labor, we would be interested in showing theoretically and empirically how standards affect technological development through market expansion and division of labor. This is, of course, beyond the scope of this study.

[14] This point was confirmed in our interviews with representatives to JEDEC from semiconductor firms that we considered were in the keep-up stage. These firms include: Hynix (Korea), VIA Technologies (Taiwan), Hana Microelectronics (Thailand).

[15] The above-normal profits here refer to technological rents that a firm can enjoy

[16] The term "standards leaders" here does not necessarily mean that the firms have a proprietary de facto standard, as in the case of Microsoft Windows or Adobe Postscript; rather, it signifies the ability of the latecomer firms to influence the directions and outcomes of the standardization efforts.

CHAPTER THREE

[17] For instance, the U.S. market represents about 37% of Samsung Electronics' total sales in 2002.

[18] ITU website, www.itu.org

CHAPTER FOUR

[19] Second sourcing refers to the situation when a firm manufactures a product designed and developed by another firm as a second source of supply for customers.

[20] Louis Branscomb, personal communication, December 2004. Branscomb is a former Director of U.S. National Bureau of Standards.

[21] Karen Colye, www.kcolye.net

CHAPTER FIVE

[22] "Samsung Ousts Sony as #1 in CE", ETR Weekly, July 28, 2005

[23] Information obtained from Samsung website at www.samsung.com

[24] Samsung's digital appliance business accounts for 6%, Digital media for 14%, and LCD for 15% of the total turnover in 2004.

[25] From interviews with Samsung former employees and current executives, April 2005, and Choi (1996).

[26] As shown in Table 5.1, the top chip equipment makers are chip manufacturers themselves. This implies that there is no direct competition between the top chip makers and the equipment makers. This creates good incentives for firms to transfer and share technologies through supplier-buyer partnerships.

[27] Information obtained from www.samsung.com

[28] Information on Samsung's participation in JEDEC is obtained from interviews with Gil Russell, Mian Quddus, Dong Yang Lee in April 2005.

[29] Information on Samsung's entry into JEDEC was obtained from our interviews with Gil Russell in April and November 2005. Russell worked for Samsung as Senior Strategic Marketing Specialist since the beginning of Samsung's JEDEC membership. He joined Samsung after working as Senior Strategic Marketing Engineer for NEC, then left Samsung to become Technical Marketing Manager for Infineon Technologies. He represented both NEC and Infineon in JEDEC.

[30] Gil Russell, personal communication, April 2005

[31] Dong Yang Lee and Mian Quddus, personal communication, April 2005

[32] ibid.

[33] Samsung website: www.samsung.com

[34] ibid.

[35] ibid.

[36] Dong Yang Lee, personal communication, April 2005

[37] An important issue worth mentioning is the prolonged series of lawsuits involving the California-based Rambus and other major semiconductor manufacturers, including Samsung, Micron, and Infineon, over DDR SDRAM memory technology included in the JEDEC DDR standards. For details, see Stern (2003) and Parloff (2003).

[38] Samsung website: www.samsung.com

[39] ibid.

[40] JEDEC website: www.jedec.org

[41] ibid.

[42] Samsung Press Release, February 10, 1999

[43] Samsung press release, February 17, 2005.

[44] Other first mass-producers of 16M DRAMs were Samsung and Goldstar.

[45] Part of the information on Hynix's standards activities is from the interviews with Hynix engineers and managers during April 2005.

[46] Information from Hana website: www.hanagroup.com

CHAPTER SIX

[47] Information on the participation of Korean latecomer firms in standardization activities was obtained through interviews with engineers and managers from those firms in April 2005, as well the follow-up email communications.

[48] http://www.affordablephones.net/HistoryCellular.htm

[49] Others strategic industries include semiconductors and computers.

[50] http://www.sktelecom.com/eng/about_skt/corp_milestones/index7.html

[51] PCS, or Personal Communications Service, is the 1900 MHz radio band used for digital mobile phone services in Canada and the United States. CDMA, GSM, and TDMA systems can all be used on PCS frequencies. The FCC, as well as Industry Canada, set aside the band of 1850-1990 MHz for mobile phone use in 1994, as the

original cellular phone band at 824-849 MHz was becoming overcrowded (www.wikipedia.com). In Korea, three PCS providers started offering mobile services at cheaper rates from 1997, with a large amount of subsidy from the government (Lee and Han 2002).

[52] According to the WiMax Forum (www.wimaxforum.org), WiMAX (Worldwide Interoperability for Microwave Access) is a certification mark for products that pass conformity and interoperability tests for the IEEE 802.16 standards. Products with WiMAX are capable of forming wireless connections between them to permit the carrying of internet packet data. It is similar to WiFi in concept, but with better performance and permitting usage over much greater distances.

[53] Information obtained from interviews with Samsung engineers in April 2004

[54] Some analysts argue that Wibro has an advantage over the WiMax standard, because it uses licensed radio spectrum. As the spectrum it uses is licensed and correspondingly protected from un-licensed use, any potential interference could be negated from other sources using the same spectrum. However, the proprietary nature of WiBro and its use of licensed spectrum that may not be available across the globe may prevent it from becoming an international standard. While WiBro is quite exacting in its requirements from spectrum use to equipment design, WiMAX leaves much of this up to the equipment provider while providing enough detail to ensure interoperability between designs. (www.wikipedia.com; http://www.broadbandhomecentral.com/report/backissues/Report0501_11.html)

In February 2002, the Korean government allocated 100MHz of electromagnetic spectrum in the 2.3GHz band, and in late 2004 WiBro Phase 1 was standardized by the Korean Telecommunications Technology Association (TTA). SK Telecom and Hanaro Telecom have announced a partnership to roll out WiBro nationwide in Korea.

[55] In November 2004, Intel and LG Electronics executives agreed to ensure compatibility between WiBro and WiMAX technology.

[56] KSA newsletter, December 2004, page 4

[57] http://www.questforum.org/index.htm

[58] LG's website: www.lge.com

[59] ibid.

[60] http://www.lge.com/about/corporate/html/company_history.jsp

[61] http://us.lge.com/AboutUs.jhtml?qs=au%7Cdetail%7Cpress%7Cpressdetail%7C0000000004%7C241

[62] http://www.atsc.org

[63] LG and Samsung are in fierce competition to lead the DMB market, both in terms of technology and standards.

[64] www.lncp.org

[65] http://www.3g.co.uk/PR/Feb2003/4889.htm

[66] www.kt.co.kr; http://www.infocom-de.com/tst/TST_2004_11.html

[67] China Daily, November 6, 2001. http://www.chinadaily.com

[68] LG Electronics website: www.lge.com

[69] We interviewed executives in the mobile communications businesses at Samsung Electronics, LG Electronics, and Korea Telecom in April 2004.

[70] www.cdrinfo.com news, June 22, 2005. Accessed November 25, 2005.

[71] There have been several cases in which standardization forums are accused of antitrust violation. A recent example includes standardization of high-definition DVD technologies. Two groups, HD/DVD (NEC/Toshiba) and the Blu Ray Group (Sony and Matsushita), are competing to create a standard for the format for high definition video. The DVD Forum, including more than 200 companies, endorsed the HD/DVD specifications.

However, Blu-Ray was accused of preventing HD/DVD from becoming the standard. Early in 2004, the US Justice Department began investigating Blu Ray for allegedly acting in concert to impede the forum's technical progress.

[72] Competitive Technologies, "Competitive technologies' patent deemed essential for mpeg-4 technology license pool" Press release March 2, 2004. http://www.competitivetech.net/pr_040302.htm, accessed January 24, 2006.

[73] Information from 3G Patent Platform website: www.3gpatents.com/history/history.html

[74] Note that Huawei Technologies of China, another emerging late standardizer, is also part of the 3G3P.

[75] Interview of Kab-tae Han, Senior manager, Intellectual Property Department, Digital Media Business, Samsung Electronics

[76] Kab-tae Han, interview for Managing Intellectual Property, http://www.managingip.com/

[77] According to Professor Sangjo Kim of Hanseong University, a job offer from Samsung indicates that the law student is a top candidate, who is likely to have a promising career as a judge or attorney. (http://cafe.naver.com/abbcccdddd.cafe? iframe_url=/ArticleRead.nhn%3Farticleid=48)

[78] http://media.jinbo.net/news/view.php?board=news&id=31900

[79] http://www.hani.co.kr/section-004100022/2004/07/004100022200407261803251.html

[80] www.telecomsKorea.com, February 1, 2006

[81] There are three service providers utilizing GSM technologies: Advance Info Service (AIS), Total Access Communication (DTAC), and TA Orange. There is one CDMA provider, Hutch; and one Digital PCS provider, Thai Mobile. The number of mobile phone subscribers in Thailand has been growing rapidly from less than 2 million in 1997 to about 15 million in January 2004. (Source: Thailand Investor Service Center: http://www.thailandoutlook.com/thailandoutlook1/about+thailand/telecom/)

[82] GSM Association website: www.gsmworld.com

[83] Chinese equipment manufactures, such as Huawei Technology and ZTE, are market leaders in Thailand's telecom network. Over US$250 million of telecom equipment purchased via e-auctions in 2004 were awarded to these Chinese manufacturers. In fact, 26% of telecom equipment and products were imported from China, the largest share among other countries including Korea and Japan. Sources: Huawei news: http://www.huawei.com/publications/view.do?id=102&cid=75&pid=61; and CS Market Research: www.buyusainfo.net/docs/x_8263753.pdf.

CHAPTER SEVEN

[84] Korea's Constitutional Court website: http://www.ccourt.go.kr/english/welcome01.htm

[85] Ibid.

[86] The Yushin Constitution made it possible for President Park Chung Hee to prolong his autocratic regime, by remaining in office indefinitely through electoral procedures. (Sources: http://www.asianinfo.org/asianinfo/korea/history/military_revolution_and_the_thir.htm; http://www.britannica.com/eb/article-34992)

[87] It is estimated that measurement process and related activities account for 3-6 percent of a country's GDP, although the level could be much lower for a developing country (UNIDO 2001).

[88] See Drezner (2004) for a case study of the influence of the states on non-state actors in Internet standardization.

[89] From KATS website: www.ats.go.kr

[90] Newsworld: http://www.newsworld.co.kr/cont/0311/28.html

[91] KSA Newsletter, No. 8, December 2004

[92] Newsworld: http://www.newsworld.co.kr/cont/0411/34.html

[93] Sanghoon Lee, personal communication, March 28, 2006

[94] TTA website: www.tta.co.kr

[95] Personal communications, April-May 2005

[96] Letter submitted by the AeA in response to U.S. Federal Register Notice Concerning Citation of The Republic of Korea under Section 1377 of the Omnibus Trade and Competitiveness Act of 1988, January 23, 2003

[97] Government subsidies for research and development are permissible under the WTO trade agreements, specifically the Trade-Related Investment Measures (TRIMs) Agreement.

[98] Examples include United Microelectronics Corporation (UMC) and Taiwan Seminconductor Manufacturing Corportation (TSMC). Both firms are spin-offs from government-owned ERSO's experimental IC factories (Amsden and Chu 2003).

[99] Source: TTA website: www.tta.or.kr

[100] An interview with Sanghoon Lee in various occasions in 2005

[101] Source: Asia Open Source Software Community website: http://www.asia-oss.org/march2004/hanoi_presentation/present/2minpresentation/03China_presentation.pdf

[102] Source: EE Times, February 01, 2006. http://www.eetimes.com/showArticle.jhtml?articleID=178600233

[103] Source: EE Times, February 01, 2006. http://www.eetimes.com/showArticle.jhtml?articleID=178600233

[104] Personal communication, Sanghoon Lee, March 2006.

[105] Personal communication, Jongbong Park, TTA officer, April 2005

[106] Personal communication, Heumjeng Kang, a KPO officer, November 2005

CHAPTER EIGHT

[107] World Bank database accessed on April 18, 2006 at website: devdata.worldbank.org/AAG/kor_aag.pdf

[108] WTO International Trade Statistics, access April 18, 2006 at website: http://www.wto.org/english/res_e/statis_e/its2005_e/its05_bysubject_e.htm

[109] The main objective of the IMF's work on financial standards and codes is to strengthen the international financial architecture that followed the financial crises in several emerging markets in the late 1990s. Source: http://www.imf.org/external/np/exr/facts/sc.htm

[110] KSA Newsletter, Number 4, August 2004.

[111] http://www.pcworld.com/news/article/0,aid,123018,00.asp

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